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THESIS

BATTLEFIELD MANAGEMENT SYSTEM: DATA REQUIREMENTS TO SUPPORT PASSAGE OF COMPANY LEVEL TACTICAL INFORMATION

by

Peter B. Polk
and
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March 1987

Thesis Advisor: Norman R. Lyons

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The major conclusions reached in the thesis indicate that the application of digital equipment to solve battlefield reporting and information processing requirements is a realistic, obtainable goal, and should be pursued. Getting a digital system into the hands of its future users is essential to the ultimate realization of BMS by allowing users to incorporate a degree of this technology into current training. Finally, the information requirements as exhibited by the activity on a voice net do not pose an insurmountable challenge with regard to the capabilities of microprocessors currently available nor do the information requirements impose any undue architectural requirements in terms of the size of random access memory (RAM) required. The struggle to communicate digitally will be driven by the graphical requirements and not the voice requirements.

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Battlefield Management System: Data Requirements to Support Passage of Company Level Tactical Information

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ABSTRACT

One of the keys to survivability on the modern battlefield is command, control, and communications (C3). A way the U. S. Army can improve its C3 is to exploit its technological advantage in the area of communications. Computers and telecommunications are reshaping our whole society in ways which will inevitably extend to the battlefield. The interactive effect of automation and communications will fundamentally alter the way commanders approach their decision-making responsibilities. Our current technology can enhance the decision-makers ability to rapidly process and distribute critical battlefield information with reliability and accuracy. Until recently, there was little effort to infuse new technology into operations at the Battalion level and below. The concept of the Battlefield Management System (BMS) will provide the integrating tool which will automate this level of operations (the tactical level) on the battlefield.

The proposed design of BMS as an electronic information gathering, processing, and distribution system, capable of handling real-time information in a responsive manner, is one such application. The technology which makes this feasible exists today, however, no definition of the parameters required to support the passage of Company-level tactical information, and to focus this application, have been established. The objective of this thesis was to quantify a minimum acceptable bound on the data bit (i.e., memory size) and the data bit rate (i.e., the speed with which a microprocessor will need to transfer the information) for BMS by structuring the voice communications architecture of a sampled unit conducting tactical exercises at the National Training Center (NTC). Additional emphasis was placed on developing a methodology for the efficient use of the communications tapes recorded at NTC in research and analytical efforts. Having derived the digital specifications from the maximum voice requirements, it was possible to quantify the positive impact BMS might have during a high intensity tactical situation.

The major conclusions reached in the thesis indicate that the application of digital equipment to solve battlefield reporting and information processing requirements is a realistic, obtainable goal, and should be pursued. Getting a digital system into the hands of its future users is essential to the ultimate realization of BMS

by allowing users to incorporate a degree of this technology into current training. Finally, the information requirements as exhibited by the activity on a voice net do not pose an insurmountable challenge with regard to the capabilities of microprocessors currently available nor do the information requirements impose any undue architectural requirements in terms of the size of random access memory (RAM) required. The struggle to communicate digitally will be driven by the graphical requirements and not the voice requirements.

TABLE OF CONTENTS

I. INTRODUCTION 13
  A. AIRLAND BATTLE OVERVIEW 14
    1. Doctrinal Evolution 14
    2. Technological Advances 15
    3. A Perspective 17
  B. AIRLAND BATTLE COMMUNICATIONS 17
    1. The Use of FM Communications 17
    2. The Use of The Battlefield Management System (BMS) 18
  C. THESIS OVERVIEW 19

II. MODERNIZATION OF THE BATTLEFIELD 21
  A. PRESENT COMMUNICATIONS IMPROVEMENTS 21
    1. Satellite Communications 21
    2. Facsimile (AN/GXC-7A) 22
    3. TACFIRE 23
    4. Mobile Subscriber Equipment (MSE) 24
    5. SINCGARS 24
    6. Position Locating Reporting System (PLRS) 25
  B. SUMMARY 26

III. BACKGROUND OF BATTLEFIELD MANAGEMENT SYSTEM 28
  A. BATTLEFIELD MANAGEMENT SYSTEM (BMS) 28
    1. General System Description 28
    2. System Benefits 28
    3. System Constraints 30
    4. Equipment Integration 31
  B. SUMMARY 33

IV. METHODOLOGY 34

A. INTRODUCTION 34
1. Command and Control in the AirLand Battle 35
2. Battlefield Management System in the AirLand Battle 36
B. RESEARCH AND ANALYSIS PHASES 37
1. Overview 37
2. Preparation: National Training Center 38
3. Data Collection 41
4. Data Analysis 42

V. ASSUMPTIONS AND LIMITATIONS 45
A. INTRODUCTION 45
B. ASSUMPTIONS 45
1. Preparation 45
2. Data Collection 47
3. Data Analysis 48
C. LIMITATIONS 49
1. Preparation 49
2. Data Collection 50
3. Data Analysis 51

VI. DESCRIPTION OF DATA 53
A. INTRODUCTION 53
B. DATA COLLECTION PROCESS 53
C. DATA REDUCTION PROCESS 54
1. Callsign Data Elements 55
2. Messages Data Elements 56
D. DATABASE STRUCTURE 57
1. Frequency Number (FREQ_NO) 58
2. Message Number (MSG_NUMBER) 58
3. Time Initiated (TIME_INIT) 58
4. Calling Callsign (CALLING_CS) 58
5. Called Callsign (CALLED_CS) 58
6. Time Completed (CS_COMPL) 58
7. Message Hierarchy (MSG_FLOW) 59

        8. Content (CONTENT) 59
        9. Time Message Completed (TIME_COMPL) 59
        10. Total Message Length (TOTAL_TIME) 59
        11. Characters Per Message (CHAR_MSG) 59
        12. Type Of Report (TYPE_REPT) 59
        13. Message Format (MSG_FORMAT) 59
        14. Activity Phase (ACTIVITY) 59
        15. Number of Characters Per Transmission One (CHAR_XSM1). 60
        16. The Text Of Transmission One (XSM1_TXT) 60
    E. INTERRELATIONAL CONSTRAINTS CONSIDERED 60
        1. Intrarecord Constraints 60
        2. Interrecord Constraints. 60
        3. Relationship Between Attributes 61
    F. SUMMARY 61

VII. DETERMINE THE VOICE REQUIREMENTS 64
    A. INTRODUCTION 64
    B. IDENTIFYING INFORMATION ARCHITECTURE 65
        1. Type Report 66
        2. Hierarchical Flow 68
        3. Type Report by Hierarchical Flow 68
        4. Activity 70
        5. Type Report by Activity 71
        6. Hierarchical Flow by Activity 74
    C. MAXIMIZING INFORMATION REQUIREMENTS 76
        1. Characters Per Second 76
        2. Establish Contact and Wait Between Messages 77
        3. Hierarchical Flow 78
        4. Activity 79
        5. Type of Report 80
    D. SUMMARY 80

VIII. DETERMINE THE DIGITAL REQUIREMENTS 83
    A. INTRODUCTION 83

B. THE DIGITAL REQUIREMENTS 83
  1. The Data Bit Requirement (Actual) 83
  2. The Data Bit Requirement (Doctrinal) 84
  3. The Data Bit Rate Requirement 85
C. TRADE-OFF ANALYSIS 86
  1. Choosing a Microprocessor 86
  2. Information Requirements 86
  3. Militarized Processors Available 87
  4. Comparative Analysis 89
D. SUMMARY 91
  1. Implication of Data Bit and Data Bit Rate Required 91
  2. Implication of Cost/Performance Analysis 92

IX. TACTICAL APPLICATIONS AND VALIDATION OF REQUIREMENTS 94
A. INTRODUCTION 94
B. ANALYSIS OF EFFECT 95
  1. Example One--Scout's Movement to Contact 95
  2. Example Two--Task Force Wire Obstacle 98
C. SUMMARY 100

X. CONCLUSIONS AND RECOMMENDATIONS 102
A. REVIEW 102
B. CONCLUSIONS 104
  1. Considerations 105
  2. Recommendations 107
C. SUMMARY 109

APPENDIX A: FORMS SUPPORTING DATA COLLECTION 110

APPENDIX B: RAW DATA VALUES 114

APPENDIX C: DATA AVERAGES AND MAXIMUMS 130

LIST OF REFERENCES 133

BIBLIOGRAPHY 135

INITIAL DISTRIBUTION LIST 137

LIST OF TABLES

1. SOURCE DOCUMENTS AND DATA SETS REQUIRED FOR MONITORING TAPES 39
2. NETS INITIALLY RECORDED 54
3. SAMPLE SIZE SUMMARY 66
4. SUMMARY OF REPORTS BY TYPE 67
5. SUMMARY OF REPORTS BY HIERARCHICAL FLOW 68
6. TYPE REPORT BY HIERARCHICAL FLOW (UP) 69
7. TYPE REPORT BY HIERARCHICAL FLOW (DOWN) 70
8. TYPE REPORT BY HIERARCHICAL FLOW (ACROSS) 70
9. SUMMARY OF TYPE REPORT SENT BY ACTIVITY 71
10. TYPE REPORT SENT WHILE IN POSITION 72
11. TYPE REPORT SENT WHILE MOVING 72
12. TYPE REPORT SENT WHILE ATTACKING 73
13. TYPE REPORT SENT WHILE IN POSITION 73
14. MESSAGE FLOW WHILE IN POSITION 74
15. MESSAGE FLOW WHILE MOVING 75
16. MESSAGE FLOW WHILE ATTACKING 75
17. MESSAGE FLOW WHILE IN CONTACT 76
18. AVERAGE AND MAXIMUM CHARACTERS, SECONDS 77
19. AVERAGE AND MAXIMUM SECONDS, MESSAGES 78
20. AVERAGE AND MAXIMUM CHAR/MSG BY FLOW 78
21. AVERAGE AND MAXIMUM SEC/MSG BY FLOW 79
22. AVERAGE AND MAXIMUM CHAR/MSG BY ACTIVITY 79
23. AVERAGE AND MAXIMUM SEC/MSG BY ACTIVITY 80
24. AVERAGE AND MAXIMUM CHAR/MSG BY REPORT 81
25. AVERAGE AND MAXIMUM SECS/MSG BY REPORT 81
26. MAXIMUM NUMBER OF CHARACTERS BY TYPE REPORT 84
27. ACTUAL VS. DOCTRINAL MESSAGE SIZES 85
28. THE MAXIMUM TRANSFER RATES 86

29. INFORMATION PROCESSING MIXES 87
30. MICROPROCESSOR EXECUTION SPEED 88
31. WEIGHTED AVERAGE MIX EXECUTION TIME 89
32. THEORETICAL THROUGHPUT 90
33. APPROXIMATE COST FIGURES 90
34. REDUCTION OF AIR-TIME BENEFITS COMPARED 92

LIST OF FIGURES

A.1 Data Record Sheet 111
A.2 Data Worksheet/Evaluation Form 112
A.3 Evaluation Form Instructions 113
B.1 Frequency One Raw Data Values 115
B.2 Frequency One Raw Data Values, Continued 116
B.3 Frequency Two Raw Data Values 117
B.4 Frequency Three Raw Data Values 118
B.5 Frequency Four Raw Data Values 119
B.6 Frequency Four Raw Data Values, Continued 120
B.7 Frequency Five Raw Data Values 121
B.8 Frequency Five Raw Data Values, Continued 122
B.9 Frequency Five Raw Data Values, Continued 123
B.10 Frequency Five Raw Data Values, Continued 124
B.11 Frequency Five Raw Data Values, Continued 125
B.12 Frequency Six Raw Data Values 126
B.13 Frequency Six Raw Data Values, Continued 127
B.14 Frequency Seven Raw Data Values 128
B.15 Frequency Seven Raw Data Values, Continued 129
C.1 Summary of Database Averages 131
C.2 Summary of Database Maximums 132

I. INTRODUCTION

It is proposed that current information gathering and distributing methods (commonly called 'reporting procedures') on the battlefield are slow, inadequate, and man-intensive when compared with the information gathering and distributing methods possible if existing technology were to be utilized to accomplish the same mission. The application of computer-based technology to the manner and method of our current reporting procedures would greatly simplify the process, provide a substantial increase in the speed of reporting, and significantly improve the accuracy, timeliness, and integrity of information problems which are a direct result of 'the way we do business' today. Part of the process in applying existing technology has to do with determining a minimum acceptable bound on the speed with which a digital information gathering and exchanging microcomputer will need to process and disseminate battlefield information at the company level in a given tactical situation. The technology which makes this feasible exists today, however no definition of the parameters required to support the passage of company level tactical information and to focus this effort have yet been established although several good starts are underway.[1] The U. S. Army's AirLand Battle Doctrine requires, among other things, that U. S. Forces sense, understand (analyze), and decide faster than the enemy can, and execute a coordinated proactive attack upon an enemy force who is still in the initial stages of executing his decision, and whose forces are not properly arrayed for combat [Ref. 1: p. 24ff]. This doctrinal statement of intent is, not surprisingly, a precursor to initiatives in technology and industry, and the maneuver-related communications aspects of the technologically feasible portions of this doctrine at the Battalion level and below is being developed under the title of the Maneuver Control System (MCS), of which the Battlefield Management System (BMS) is a part. It is in the area of defining and sizing the information requirements that this thesis will make its greatest contribution. The motivation for this focus was driven by the declaration in Reference Two, page B-5, that the data requirements to support the passage of Platoon-level information were unknown. It was this unknown that this thesis will quantify.[2]

---

[1] Work at the Communications and Electronics Command (CECOM) at Ft. Monmouth, NJ, and at the Signal Center at Ft. Gordon, GA, is underway to define the basic information flow in order to support a systems design decision, but their perspective is at the Corps and Division level. The only place where a Battalion level and below analysis is occuring is at the Directorate of Combat Developments at Ft. Knox, KY.

A. AIRLAND BATTLE OVERVIEW

1. Doctrinal Evolution

The relationship between doctrine and experience is a dynamic one, which results in experience being functionally linked to an industrial response through our doctrine. Our experience, and the experience of others, influences our doctrine, and it is our doctrine which sets the requirements for industry. The AirLand Battle doctrine is no different. The doctrinal expression summarized by the AirLand Battle has, as its roots, a visible logical connection with the U. S. Army's experience in Vietnam. The characteristics of that conflict (mobility, firepower, air superiority, lack of clearly defined enemy, immediate command presence at the battlefield)[3] drove the industrial expansion in areas which sought to maximize our effectiveness in these same areas where light, air-mobile forces were the preferred means of fighting the battle in a low-intensity conflict. One link, the blurring of the traditionally linear battlefield, began here [Refs. 3,4,5,6,7,8]. Following Vietnam, the doctrine of the Active Defense expressed the U. S. Army's definition of the way it saw to best defeat an enemy force capable of attacking anywhere at will, one whose numerical superiority required a reflexive and responsive reaction on our part. It was an effort wherein U.S. Forces traded ground against the enemy's strength and attacked his weaknesses.

It was at the time of the U. S. Army's formal adoption of the Active Defense that the Arab-Israeli wars in the 1970's began. These conflicts can be characterized as conflicts of heavy (mechanized) maneuver, firepower, and leadership-involvement, wherein the requirements for both offensive and defensive weapons systems capable of deep armor thrusts and of defeating such a thrust, were once again employed [Refs. 9,10]. These conflicts validated the maneuver warfare orientation of our doctrine but refocused our need to realize the same objectives in countering a heavily armored threat in an European scenario with an armored and mechanized (heavy) force.

---

[2] As explained in Chapter Four below, NTC tapes of the Platoon-level specifically were not available for research, so the authors focused their study at the Company-level, capturing the reflection of the platoon nets as heard on the company nets.

[3] These characteristics appear to be the common consensus derived from several sources, some professionally presented and pro-U.S. involvement in Vietnam, others less so, some written by Army Officers, some by observers, and some are somewhat more colloquial.

Correspondingly, the weapons which the U. S. Army purchased were either armored or capable of accurate, long-range, lethal anti-armor target destruction, and were mobile, reflecting our commitment to this type of warfare.

The Active Defense became the Extended Battlefield, then the Second Echelon attack.[4] The awareness of our need to fight in something other than the linear battlefield is expressed in these doctrinal titles as the U.S. Army attempted to initially define the problem and express its solution in tactically and technologically feasible terms. The AirLand Battle doctrine represents that umbrella concept under which the utilization of our modern systems are to be exploited. In fighting both an immediate attack and a coordinated long-range, disruptive attack, U. S. Forces intend to deny the initiative and freedom of movement from the enemy, delay the arrival of his follow-on forces in the time and strength originally intended by the enemy, and maintain control of the battlefield through proactive maneuver warfare which recognizes enemy intentions before he executes them and defeats him before he is able to sufficiently organize his assets. Time-sensitive decisions, made at all levels of command, compete for limited resources in defeating an enemy force. The allocation of these resources requires accurate information from the lowest possible echelon involved in the fight, and this thesis will focus on defining the Company-level tactical information requirements as depicted by two Battalion Task Forces at the National Training Center (NTC).

2. Technological Advances

The implementation of the AirLand Battle doctrine presupposes an effective and efficient communications system. Current doctrine calls for U. S. combat forces to maintain the initiative on the battlefield, function (look and fight) in depth in both time and distance, demonstrate agility against a numerically superior force, and operate together synchronously so as to achieve a synergistic effect far greater than the mere sum of the effects of the individual units on the battlefield [Refs. 11,12: pp 1 - 24]. To this end, important advances in firepower, mobility, and survivability have been introduced and fielded in the past ten years. In the area of firepower, the weapons on the battlefield today exhibit an increased probability of hit, carrying an increased payload over an increased distance in both direct fire and indirect fire weapons systems. The weapons platform itself is more capable and stable, and we can achieve increased armor penetration through increased gun size, increased muzzle velocity and better munitions. We are deploying munitions capable of attacking the weaker top armor of enemy tanks, and are exploring the usefulness of tandem warheads to degrade enemy armor upgrades. We have increased the accuracy of our target acquisition, identification, and designation systems (whether thermal, optical, electromagnetic or visual in origin), we employ remotely piloted vehicles (RPV) and smart munitions, and entertain ideas of controlled nuclear warfare heretofore undefined. Finally, we are exploring the utility of electromagnetic tank guns and hypervelocity missiles for use on the next battlefield.

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[4] Technical terms taken from the article by Major Chess Hess, appearing in the June 1986 *Command and Control Microcomputer Users Group* (*C2Mug*) newsletter, Ft. Leavenworth, KS, Vol V, No. 5.

In the area of mobility we have realized a greater than proportional increase in engine power and performance as compared to increases in vehicle weight, and have reduced the ground pressure per inch requirements of our vehicles through improved suspension systems and better weight distribution. We have generally increased the cruising ranges of our combat and combat support vehicles, and have significantly increased our night-fighting and all-weather combat capability. The weather and daylight constraints which hampered our previous warfare are diminishing. Additionally, we have increased our utilization and development of the helicopter in combat and combat support operations, overcoming the constraints of terrain imposed upon ground mobility systems.

In the area of survivability, we have increased the level of performance of our armor (whether spaced or reactive-armor) by increasing its round-defeating and crew-protecting capabilities. We have increased the mobility of our vehicle fleet across the board, which is a significant contribution to survivability itself. Efforts are underway to reduce the crew-size on our combat vehicles through advanced vetronics, which further improves crew survivability. NATO-interoperability and commonality of repair parts are additional factors strengthening our combat force. Additionally, we have increased our electronic-warfare capabilities (both offensively and defensively), we have increased our battlefield engineer capability to canalize and slow the enemy while at the same time improving our obstacle-breeching capabilities, and are restructuring our logistical resupply procedures in both doctrine and with more capable vehicles in order to increase the efficiency and throughput of the resupply process. Finally, improvements in fire suppression (dual-spectrum fire sensing and suppression systems) further guarantee the survivability of our combat vehicles and crews if they are hit.

3. A Perspective

However, the bane of these advances upon which AirLand Battle doctrine depends is that the same improvements are occuring in our opposing forces units. Additionally, the technological advantage U. S. forces enjoy is insufficient to overcome the massed firepower, personnel, and munitions which the Warsaw Pact Forces can bring to bear at a critical point on the battlefield [Ref. 13]. Soviet doctrine emphasizes mass, momentum, and continuous combat in an attempt to fix friendly forces, create a breakthrough, and then exploit it while continuing a high rate of advance towards its objectives [Ref. 12: pp. 5ff.]. This combat is also extended in depth in both distance and time as Soviet Forces utilize their airborne/airmobile forces to disrupt friendly operations in the rear area. They, too, recognize that it is possible for them, in the event of war, to "extend immediately active combat operations not just to the border regions, but to the whole of the (enemy's) territory, which was not possible in past wars" [Ref. 14]. Additionally, their operations will be facilitated by shorter supply lines and closer supply sources. We will not enjoy the luxury of time afforded us in the past by our allies who absorbed the initial enemy attacks, permitting us sufficient industrial-base planning and preparation, population mobilization and training prior to entering the war, finally bringing the weight of our advantages and skill to the battlefield after the onset of hostilities during which our enemies have begun to deplete their resources prior to our arrival.[5] The disposition of our forces is different now than they were 'then'. We are now faced with a 'come as you are' war, and it is to a brief overview of existing battlefield communications that we now turn.

B. AIRLAND BATTLE COMMUNICATIONS

1. The Use of FM Communications

The combat force multiplier which links the entire scheme of maneuver is the communication system, and it is in this arena that BMS provides a significant improvement over existing FM voice communications. Little has been done at the battlefield level since World War II to improve communications. While improvements in the methods, means, and protocols have been implemented at higher levels of command (Corps-level Tactical Satellite Links, Corps-level Tactical Record Traffic Facsimile, Corps-level Command and Control Information System (CCIS), Mobile Subscriber Equipment (MSE)), FM voice is still the primary means of communication at the tactical level. The same conclusion is drawn in Reference 15, page 2-2. But FM voice is no longer the effective tool it once was, given the changes which have occured on the battlefield with respect to the requirements of U. S. Forces (particularly at the Battalion-level and below) to coordinate an array of (limited) resources controlled at different echelons of command, and with regard to the current capabilities of the Warsaw Pact Forces. It is subject to interference, attenuation, and bleed-over from stations on adjoining nets, especially in a hostile environment where the enemy is seeking to denigrate your communications capabilities through jamming, and to target you for his next artillery mission through his radio direction finding (RDF) measures. Additionally, because it is slow, neither is FM voice a suitable medium to handle the the volume of information required during normal tactical operations: typical U. S. Forces Tactical Operations Standard Operating Procedures (SOP's) specify elaborate schemes of hand-carried hard copy reports to overcome the obvious shortcomings and signature of FM voice single-channel communications. However, this creates a significant time gap between when events actually occur on the battlefield and when they are recorded at higher Headquarters as having occured with the result that Battalion and Brigade commanders display and work with outdated information as they make decisions and finalize future plans. The link upon which successful execution of our combat plans is now the weakest link in the implementation of these same plans, namely, our current communication system. See also Reference 16, pages 2 and following. Another solution to battlefield information reporting must be developed in order to maximize what few technological advantages remain ours. The same conclusion is drawn in Reference 12, pages 23 and 24, and Reference 15, pages 2-1 and 2-2.

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[5] A similar note of caution is expressed by Lt. General Robert W. RisCassi, on page 193 of the annual Army 'Green Book', October 1986.

2. The Use of The Battlefield Management System (BMS)

BMS is a computer-assisted, distributed command and control device focused at synchronizing the five points of the SIGMA STAR (fire support, intelligence/electronic warfare, maneuver, combat service support, and air defense artillery) at the Battalion-level and below. It is designed to assist in the coordination of the battle by helping decision-makers at the Battalion-level and above decide where and how to best allocate limited resources, based upon the most accurate and most timely information possible from the Battalion-level and below, which BMS will provide. Ultimately, BMS will speed up the decision cycle of commanders on the battlefield, compressing the time it takes him to reach a conclusion and then communicate that conclusion to his subordinates. It gives commanders the ability to anticipate his own needs, and plan proactively for them. instead of merely reacting to them as they arise on the battlefield. Control. integration. and synchronization of assets on the battlefield will be enhanced through BMS.

It is the goal of the BMS to provide the integrating tool which will automate some standard inputs to many recurring reports (such as unit identification. location. status reports on fuel, ammunition, personnel, orientation, and current activity) and facilitate collection of the remaining few inputs so that report-generation time is drastically reduced and simplified. This will provide for accurate information being accessible where it needs to be, on time, up-to-date. and will help realize and coordinate the AirLand Battle doctrinal objectives. But without a significant improvement in the manner in which we think about how we communicate. it is the authors opinion that AirLand Battle Doctrine may not be fully realized. See also Reference 17 and the article in Reference 18.

C. THESIS OVERVIEW

The primary focus of this thesis is to quantify a minimum acceptable bound on the data bit and data bit rate required for a system such as BMS in order to provide a magnitude of order scale on the capabilities of any microprocessor for BMS. To this end, Chapter Two will outline existing methods which strive to improve communications and to report accurate information on the battlefield and will discuss the shortfalls of the most recent ones in light of the desired capabilities of the integration available in a full-scale,. fielded BMS system. Chapter Three will provide some background on BMS as a whole: where the ideas began. how has BMS evolved over time. and what is currently expected in the BMS package. Chapters Four and Five will detail the assumptions and methodology which framed our research effort to establish the validity of our basic model upon which the data bit and data bit rates depends. Chapter Six will describe the raw data obtained from actual FM-voice tapes of units at the National Training Center (NTC), Ft. Irwin, CA. which was our data base, and will explain the data reduction methods and the variables utilized in modelling the information flow of US maneuver units in (simulated) combat. Chapter Seven will then define the requirements for the passage of battlefield information given the actual voiced-based information flow obtained and the model described earlier. Chapter Eight will digitize the voice-based requirements in order to establish the data bit and data bit rate minimum acceptable bounds, and will explore the impact our derived requirements will have upon architectural (or technological) decisions, such as microprocessor data transmission requirements, and memory requirements for imbedded reports. Chapter Nine will explore the potential advantage which may have been realized had one of the units at NTC had BMS available to them during the conduct of their fight, and will attempt to depict the increased combat effectiveness and realization of AirLand Battle objectives which are inherently potential with BMS. Chapter Ten will summarize our conclusions and will present our recommendations for the implementation of BMS. We presume that a fully mature system will not be fielded at the outset, but that the capabilities for the mature system must be. We will provide comments on the direction of growth which may yield the most immediate gain and productivity. This will be followed by the appendices and a detailed bibliography.

II. MODERNIZATION OF THE BATTLEFIELD

A. PRESENT COMMUNICATIONS IMPROVEMENTS

The U. S. Army has, in the most recent ten years, attempted to 'modernize the battlefield' by applying mature computer technology towards overcoming some of the long-term problems that have plagued our maneuver forces reporting capability. While the advances in firepower, mobility, and survivability (described above) have largely been mirrored in the Warsaw Pact Forces, our recent advances in computer-assisted communication programs have not. A brief discussion of the most recent attempts follows.[6] Our analysis will describe the newest systems which are currently fielded, or are programmed for fielding, but will ignore the large field of candidate systems still competing for utilization by the Army.

1. Satellite Communications

The tactical satellite multichannel terminal, anti-jam protected link, operating on a super high frequency (SHF), is known as the AN/TCS-85(V)2. It operates within the 225 to 400 MHz bandwidth in a single-channel configuration, and in the 7250 to 8400 MHz bandwidth in the multi-channel mode. Access to this device is provided to units down to the Brigade level. The system provides an increased data flow capacity and a highly reliable microwave line of sight link capable of operating over a greatly extended range without the need for a relay station. It is one of the primary methods used to link with the strategic communications system, and thereby relay information to decision-makers at the national level. In addition, it provides the capacity to designate one station as a multiplexor to link up to four other stations in a full-duplex mode so that broadcasting techniques and 'conference calling' can be used to provide those users with simultaneous information access. This flexibility alone is a significant improvement over older closed, non-expandable half-duplex satellite communications systems. It is capable of operating in the secure, non-secure, or pulse code modulated (PCM) mode, at a rate of 16 thousand bits per second (which is the maximum capacity for SINCGARS, see below), so that it is compatible with any communications system which Brigade sized units typically employ both now and into the near future. It will support up to 96 voice and data channels of pulse-code modulated (PCM) data on a single SHF frequency. While meeting the needs of Brigade and higher commander's, this system does nothing to facilitate the collection and reporting of information at the battlefield level.

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[6] The failures, such as the enormous undertaking attempted in the Tactical Operating System (TOS), will not be examined unless suitable in demonstrating a problem area to avoid, i.e., unless they provide a 'lessons learned' principle for this context. Additionally, those computers specifically linked to a weapons system to assist in target acquisition (like the Short Range Air Defense (SHORAD) system, or the Air Defense Anti-Tank (ADATS) System), will not be discussed.

2. Facsimile (AN/GXC-7A)

The tactical facsimile equipment (AN/GXC-7A) was fielded to primarily assist commanders at all echelons from the Battalion on up in exchanging graphical information (such as front line traces and other tactical planning overlays) and extensive numerical information (such as air and artillery target lists, unit locations, resupply points, etc...) by a secure means, using existing FM radios and encryption (secure) protocols, and to reduce their dependence on air or surface messengers, particularly to dispersed or isolated units. It is a flexible and rapid[7] system designed to overcome the problems of the existing teletype equipment. This older teletype equipment did not permit the exchange of maps, graphs, overlays, or charts at all, except by default (i.e., by a messenger system, ground or air, which induced an inherent time delay and an element of insecurity). The teletype equipment required the operator to re-enter the desired information again, textual or numeric only, thus increasing the possibility of inducing error and adding a time delay into the communication process. By contrast, information received by the facsimile is automatically capable of immediate retransmission to all units similarly equipped, from the Battalion through to Corps levels. Additionally, the facsimile does not require a dedicated operator, thus freeing up a soldier from the restrictive and time-consuming job of running a teletype machine. The problems of teletype inefficiency, its time and people requirements, as well as its being a source of delay and of inducing error into the system have all been eliminated by the successful fielding and continued utilization of the facsimile equipment. The major objection with this equipment is that it is too large and weighs too much to be used within each combat vehicle that the U. S. Army operates. Other man-machine interface issues (how to input data, the battlefield constraints of temperature and dirt, among others) also prohibit its direct utilization as a viable solution to the existing problems associated with battlefield-level command and control.

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[7] Up to five times faster than the teletype equipment it was replacing, according to an article published in FC 101-34, *Command And Control On The AirLand Battlefield, Selected Readings*, page 556, published by the Command and General Staff College, Fort Leavenworth, KS, June 1984.

3. TACFIRE

The most recent and most technologically advanced piece of equipment fielded through the Field Artillery channels to support the maneuver commander is known as TACFIRE, and is based upon 1950's technology. It is a digital information reporting device with subcomponents which will compute individual quadrant and elevation solutions for each gun in a battery, and which provide a means to record all fire missions requested and shot (i.e., it has an archival record storage capacity). Additionally, it permits the Fire Support Officer (FSO) to assign and change priorities to fire missions and targets in order to respond to changing requirements on the battlefield. It utilizes an end-to-end message acknowledgment system to verify that what was sent is what was received, and permits the simultaneous integration of up to eight different reporting units (nets). While promising to improve field artillery responsiveness to maneuver commanders at the Battalion level, TACFIRE is unfortunately plagued with peripheral problems caused by its being reliant upon the existing (old) radio communications network to transmit its digital messages. 'Its operational requirements do not conform to the operational realities of U. S. Forces in the field which correspondingly detracts from its utility and potential positive impact. These requirements include a necessity for a very finely tuned radio frequency match between reporting units to within one Hertz. While theoretically achieveable, the reality of the situation is that the radios in use now are approximately twenty years old and are so worn that adjustments made to such a fine specification do not long retain that adjustment. When that happens, communications cease. Additionally, since the keying time of passing digital information is much shorter because it is faster than passing the same information by voice, the cooling fan of the radios involved often do not activate in order to cool the radios, which results in over-heated (i.e., inoperative) radios, and, once again, communications cease. It is hoped that the fielding of the new family of radios (SINCGARS, see below) will resolve these problems and permit TACFIRE to operate the way it is designed to do. The TACFIRE system is capable of being mounted on any number of tactical wheeled or tracked vehicles and is therefore as mobile as the unit to which it is deployed. However, TACFIRE is still too large and too cumbersome and is not 'user friendly' enough to be considered as the solution to the current problems.

4. Mobile Subscriber Equipment (MSE)

Recognizing that neither stationary command posts, nor those requiring a long time to install and to remove, nor those with large electromagnetic signatures will probably survive on the next battlefield, a highly mobile communications system, capable of providing secure jam-resistant voice, data, and facsimile communications to Corps and Division Commanders is a necessity. The MSE system is designed to provide that, and consists of three separate components which interface to provide automatic self-regulating control of the system while creating the appearance of a dedicated communication link between two parties. It provides a terminal (workstation) for lengthy data message input and for the preparing, sending, and receiving of graphics (facsimile), as well as a light weight mobile digital radio telephone link for mobile operations supporting only voice and data use. MSE is capable of linking with wire as well, and interfaces with Echelons Above Corps (EAC), other U. S. Military Services, Joint and Allied Commands, Tactical Satellite Links, as well as commercial telephone systems. It is a versatile system designed to afford the maneuver commander the communications he requires to support the mobility of his forces. Its prime mover is the high-mobility, multi-purpose wheeled vehicle (the HMMWV), which is air transportable on military aircraft, but is deployable with tracked vehicles as well. Like SINCGARS, this is not yet fielded and provides no increase in capabilities to the units on the battlefield, and once it is fielded, it will extend down only to the Battalion level, so that once again the units doing the fighting are not provided any state of the art communications equipment to assist them in their primary job, which is fighting and winning.

5. SINCGARS

The Single Channel, Ground Airborne Radio System (SINCGARS) is the new family of military standard radios intended to replace the existing AN/VRC-12 series of radios. It is a long needed but not yet fielded product whose major fielding goals include an increase in the reliability of the tactical command and control communications systems, a modular design approach which will facilitate equipment repair and permit incremental growth to be applied as even newer capabilities are developed (i.e., it is an 'open' system), and compatibility with other command and control systems through the utilization of common circuit boards as well as other major components. These general areas of system improvements have been the obstacles to the continued growth and future use of the existing radios. SINCGARS will allegedly increase the number of channels available for use to ground forces from the existing 920 channels available to 2,320 channels, by operating in the 30.000 to 87.975 MHz range, in 25 kHz intervals [Ref. 19: pp. 1 - 11]. This radio system will be common to all ground vehicles, and will therefore be capable of supporting the communications requirements of all maneuver units, from the individual vehicle level and up. It will have the capability to operate in either a plain or encrypted mode. with or without utilizing its own electronic counter-counter (i.e., frequency hopping) measures. It will be fielded with some inherent nuclear hardening built into the system. while at the same time providing a significant reduction in the weight requirements of up to fifty percent. It will accept digital data at input rates ranging from 75 bps to 4,800 bps, or analog data at rates less than 1,200 bps. This is converted to 16 kbps to provide for error detection and correction. Synchronization is provided by an internal clock, but time discrepancies as large as one minute can be tolerated and communications will be established automatically [Ref. 19: pp. 12 - 33]. However, the system is not yet fielded, and so provides no genuine relief to maneuver commanders yet, and if fielded without a digital system capable of exploiting its transmission capabilities, then its only advantage will be its increased secure operations mode and its reduced weight.

6. Position Locating Reporting System (PLRS)

Currently still under testing and evaluation by both the Marine Corps and the Army, the PLRS consists of a UHF radio transceiver operating within the 420 to 450 MHz spectrum linked with a microprocessor which automatically communicates with its Master Unit at least once a minute. In this way the position of friendly forces is accurately relayed, real-time, up the chain of command, and the user is not involved in the process at all. It's reports are accurate to within fifteen meters (according to current specifications), and can be used to coordinate artillery, air, and naval gun fire to support combat operations. Accurate location determination is a function of the time of arrival of the message updating the unit's position, which will be a function of the distance of the sending unit from the Master Unit. Because the Master Unit knows when the message should have arrived (based upon a known assignment of a time period), by calculating the difference between the two times, and through a process of triangulation, the location of the user is determined. One Master Unit will support up to 370 different reporting units, spread out over a distance of up to 2,300 square kilometers for ground forces and up to 90,000 square kilometers for airborne forces.

This coverage is possible because each PLRS unit can act as a repeater for any other PLRS unit. PLRS incorporates a time division multiplexing scheme in order to handle this quantity of information from its subordinate units, with each user receiving at least one of the uniquely identified time divided slots. Each slot is one-quarter second in length, and is divided between 128 users. During this small unit of time (1,950 microseconds) a maximum of 94 bits of data is transmitted in 800 microseconds. The remaining time (1,150 microseconds) is used to provide the necessary buffer and overhead between adjacent assignments. PLRS utilizes three processors to achieve this: two AN/UYK-20 processors and one AN/UYK-7 processor. One of the AN/UYK-20's handles network control and related network management tasks; the other provides input/output processing for the system itself. The AN/UYK-7 is used to perform the calculations involved in calculating the users position [Ref. 20]. Unfortunately, this system is not yet fielded either, however it does begin to approach (in this one functional area of position reporting) a viable solution to the issue of overcoming problems related to battlefield reporting and information distribution.

B. SUMMARY

It should be obvious now that little has been done at the battlefield level (i.e., the Battalion and below) since World War II to improve communications for the maneuver commander. While much appears to be available 'just over the horizon'; these improvements are still up to six or eight years away from being provided to the commander responsible for fighting the enemy on the battlefield. So, while improvements in the methods, means, and protocols have been implemented at higher levels of command, FM voice is still the primary means of communication at the tactical level.[8] The irony of the situation is that the combat force multiplier which links the entire scheme of maneuver is the communication system, but nothing has been fielded to provide a state-of-the-art system to that level of command and control. An analysis of the current decision-making process within a Battalion Task Force conducting dynamic operations similar to what is required by AirLand Battle doctrine describes the Battalion staff as being ". . . hard pressed . . . (and) hampered . . . by sluggish information processing and manual handling . . ." of data in order to provide accurate pictures of the battlefield to support accurate decisions and to generate the necessary reports to execute those same decisions [Ref. 21: p. 1]. It is in this arena that BMS provides a significant improvement over existing FM voice communications, and it is to an overview of BMS that we now turn.

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[8] The same conclusion is drawn in Abram, J. M., Kinion, P. D., Gibbs, G. G., *Initial Candidates Report For The ADDCOMPE Battalion Domain Study*, a study prepared for the Defense Advanced Research Projects Agency (DARPA) and the U.S. Army's Communication and Electronic Command (CECOM), September 1986, page 2-2.

III. BACKGROUND OF BATTLEFIELD MANAGEMENT SYSTEM

A. BATTLEFIELD MANAGEMENT SYSTEM (BMS)

1. General System Description

Based upon the introduction to BMS provided in Chapter One, BMS can be summarized as being an an electronic information gathering, processing, and distribution system. handling real-time battlefield information in a responsive manner. It must be designed to ensure the reliable transfer of battlefield information through the use of an end-to-end or a switch-to-switch data acknowledgment. The protocols selected for its operating system should be capable of automatically routing messages according to its self-monitoring and flow control specifications. BMS should support the same desirable features of our current system, such as establishing a hierarchy of priorities and levels of security. but should improve upon the method these flexibilities are implemented. Should a unit in the network become dysfunctional, not only must BMS be capable of routing messages around it (i.e., there should be no single point of failure), but it must be capable of querying that node as to its status and reconstitute it if necessary.[9]

2. System Benefits

BMS will unstress the battlefield fighter by reducing his own involvement in the reporting process, thereby freeing him up to concentrate on fighting the battle. It is the application of technology to this precise area that will provide one of the greatest benefit to maneuver commanders. BMS will facilitate timely and well-founded battlefield decisions at the fighter level. i.e., at Battalion and below. It will resolve current problems regarding the accuracy. accessibility. timeliness. and integrity of battlefield information. Because everyone will have the same 'view' of the battlefield, and because data will be updated automatically through hardware and software protocols, decisions will be based upon the best information available. The Commander will be able to see the battlefield in a fashion typified by the echeloning of Commanders above the battlefield in helicopters in Vietnam. except that now this command and control is not realized physically but logically.[10] Enemy targets and locations will be known by their being lased by friendly vehicles, reports will be accurate and real-time, and the status of any unit on the battlefield (with regard to fuel needs, or ammunition shortages, among others) will be available instantly, without the involvement of the people who 'own' this data, i.e., the people doing the fighting. Conducting logistical and tactical planning and executing those plans will be simplified because the exact nature of the requirements will be known to the decision-makers.

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[9] BMS, generically, represents more than just a communications device. It incorporates other vehicle improvements directly related to fighting the battle. like the Commander's Individual Thermal Sight (CITV) and an identification of friend or foe (IFF) function. but these aspects of BMS will not be addressed here. Our focus is on the communications-related improvements necessary to support the Inter-Vehicular Information System (IVIS).

The ability to access this information will be available from any BMS-equipped vehicle through the use of passwords to protect unauthorized access to information not necessary at a particular level. This capability to access the entire database from many locations on the battlefield contributes towards increasing the mobility of a commander, because he is not tied to one particular vehicle or location. This capability to rapidly and frequently displace will contribute to his overall survivability as well. Additionally, data survivability is increased through the duplication of the database and the ability to access it at several locations throughout the battalion command and control structure across the battlefield.[11]

With command functions now dispersed, and capable of near real-time communications from different locations, the command and control of a battalion is harder to detect and therefore harder to degrade or to kill. Neither is there now any single point of failure for the command and control of a maneuver battalion. Should any command and control element be eliminated, the degradation of the systems performance will not be total. The dispersion of the functional elements of a battalion's command and control structure will permit their incremental displacement which will present a (hopefully) confusing and constantly changing electromagnetic signature to the enemy and will permit greater command and control of the battalion as a whole during fluid periods. It will also permit a better utilization of the terrain by the various command and control elements because their functional size has been reduced and the requirement for them to co-locate has been eliminated.

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[10] A warning is necessary here to guard against the non-utilization of the chain of command and the resulting abuse of BMS which is possible because of its information collecting and reporting capabilities and its ability to transcend the normal hierarchical flow of information and command and control.

[11] The idea of a 'replicated' database is also recommended by the work at Ft. Lewis, WA, by Army Development and Employment Agency (ADEA) in connection with the 9ID (MTZ), and the Communications and Electronic Command of Ft. Monmouth, NJ. Many of the ideas above derive from their documents. See the bibliography.

Because BMS is conceived to be a packet-switched radio network, the amount of time spent on the radio will be reduced.[12] This reduction is possible because the information to be relayed will be broken down and organized into manageable packets of data which will be passed digitally, without the time-delays associated with mechanical switching involved at all. Because net utilization time will be reduced, the entire infrastructure will be relaxed and more responsive, and the reduced activity may disguise a tactical operation underway, normally recognizable by the increased number of transmissions which occur. Additionally, if net utilization is reduced sufficiently, it may become possible to assign one frequency to many users in a way that is transparent to them but which permits the overall reduction of nets in use by a battalion, which will reduce its total electromagnetic signature even further. When contrasted with the Soviet radio direction finding capabilities (they are able to identify a target to within 250 meters of its actual location after thirty seconds of radio transmission time), BMS provides an impressive, much needed capability. See Reference 16 for an easy to read and understandable presentation of the same ideas.

3. System Constraints

Present constraints have to do initially with the size and weight of the proposed hardware. BMS will be placed inside each combat vehicle in the U. S. Army's inventory, and selected combat support and combat service support vehicles as well, but the requirement to add more weight and place more equipment ANYWHERE on any vehicle is approaching the upper limits of its advisability.

The second area of concern has to do with the harsh operational environment of the equipment, including the shock (from both cross-country operations and the firing of the weapons), and also the dust, dirt, and sweat present in the normal course of everyday operations. The presence of corrosive fumes released into the turret from the firing of the weapons, the temperature and weather extremes the vehicle and crew is expected to operate in (like snow, rain, mist, dust, humidity, to mention a few), and other operational realities, all contribute to restricting the choice and defining the operational capabilities of any microprocessor under consideration for use with BMS.

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[12] The decision on how to best implement the information protocols is outside of the focus of this thesis, and the packet-switched option is assumed in order to provide a point of reference for comparison between what BMS may provide and what is available now. To give the reader an idea of what is possible, ADEA utilizes a variable packet size for its messages, varying between 400 bytes to 2 Kbytes in size. The size of each packet is adjusted automatically by the system controller in response to the real-time performance of the system. A greater delay in a packet reaching its destination results in the system generating shorter packet sizes in order to stabilize the average delay and increase throughput.

The soldier-machine interface issues with regard to screen and keyboard size and style are perhaps the most lively areas of research. Deciding on the technique to be used to speed up or compress the entry of data is one of the most complex issues to be decided. See below for the discussion of the touch screen/display panel options.

Finally, the obvious restrictions of the cost of the components and presently unknown funding constraints imposes the final constraint. A cost/performance analysis must be conducted, but until the basic components of the system, and their impact upon the performance of elements on the battlefield can be measured (quantified), the choice of a computer-assisted system to perform these functions will be frustrated. Additionally, defining the exact measure of performance (whether is is throughput, or the number of instructions executed per measure of time, or reliability) must also be prioritized and figured into the overall acquisition strategy.

4. Equipment Integration

The objectives and benefits detailed above are realized through the integration of a plethora of existing and yet to be fielded items of equipment [Ref. 22].

a. On-board Sensors

On-board sensors currently exist which will assist in the collection of information relating to the fuel status, the firing of the main gun, and the maintenance status. These are all tied to the MIL-STD-1553B data bus which already exists on the vehicle and passes analog signals to the pertinent crew member to provide them a status of the system as it is currently performing. Yet to be fielded facets include an alert to the tank commander when any sensor detects or reaches a predefined, mission related, critical level, and a link to connect the firing of the main gun with a preindexed round count to maintain an accurate ammunition status.[13]

b. Vehicle navigation Aid System (VNAS)

Yet to be fielded, the navigational and position reporting device will automatically disseminate the vehicle's position and heading and will reflect the turret orientation relative to the front slope of the vehicle. This system will show the vehicle's location on the BMS screen, and will give everyone with whom this vehicle's processor communicates instantaneous knowledge of his position and heading, and a sense of what that vehicle is doing (i.e., moving, in position, or scanning for targets). It will assist in executing any rapid changes of missions, and will link with the laser rangefinder (discussed below) to assist in identifying the location of an enemy, automatically. Ultimately, this system will help reduce the 'fog of war' by maintaining and relaying accurately the position of a particular unit.

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[13] A feature which the authors think would significantly enhance user acceptance of BMS would be to permit BMS to remain on, in a running state, even while the vehicle is being started up. Current requirements to shut off the radio when the vehicle is started are a hinderance, and the elimination of this outdated technological concession would not only increase the users acceptance of BMS but would permit this critical battlefield system to remain operational as the vehicle and crew transition tactically from a turret-defilade position, with engine off, to a hull-defilade position, with engine on, in order to engage a target or support any other tactical activity, without having to lose contact with the battlefield by having to shut-down BMS.

c. *Laser Rangefinder*

The existing laser rangefinder will be linked with the existing data bus, and will be used to automatically compute, display, and relay information regarding the location and range of a target from the location of the vehicle lasing to it with the assistance of the VNAS system described above. This combination will free up the fighter from having to go through the time-consuming process of determining the enemy's location from a map while he is at the same time attempting to acquire and destroy the same target. BMS will unburden the fighter, and unstress his involvement in the reporting process through the interplay of its systems components, and will thereby contribute to the survival of the crew.

d. *Imbedded Reports*

The most frequently used reports will be imbedded in the memory of the BMS system, and will facilitate the gathering, processing, and formatting of pertinent information. Other required reports will be available, and may either be resident within the memory of each BMS-equipped vehicle, or may be accessed from a larger database of reports imbedded in BMS at the Battalion terminals. Such a memory hierarchy may permit the system on-board a fighting vehicle to be functionally streamlined to assist in fighting the battle, and require other memory- or textual-intensive requirements (reports, checklists, among others) to be stored in an accessible location somewhere other than the vehicle itself. These decision aids will provide a standardized format, a common language, and a continuity of operations by supplying everyone in the chain of command with the same structure within which to work. Training aids and other memory-prompts (like a checklist containing the Troop Leading Procedures, or the format for a five paragraph Field Operations Order) will help assure that the planning necessary to conduct an operation or to conduct training is properly addressed, and will contribute to making good leaders even better.

e. *I/O Device (Touch Screen/Display Panel)*

The exact nature of the input device is yet to be defined, but a touch screen format coupled with a light pen or an abbreviated keyboard with preset function keys (hand size), is the most likely combination of input devices. Whatever it ultimately is, it must be fast and accurate, and must support the way the fighter fights the battle. An abbreviated keyboard may be functional for planning and for use in a resupply/consolidation phase, when the battlefield is stable or no immediate threat exists, but it is the authors opinion that a keyboard would be dysfunctional in combat. Therefore, the design of the system should focus in other areas. An analysis of voice synthesizers and expert systems to facilitate input is a technologically achieveable and perhaps not a cost-prohibited choice either. Voice digitization might be the fastest means possible, one which mirrors the way we report now, and would require the least amount of retraining for vehicle crews. A covered mouth-piece (similar to what fixed-wing pilots wear) to block out extraneous noise, could be linked to the NBC protection system, providing two functions in one.

In terms of the output device, a display panel is the most logical choice because it permits the use of graphics discussed above in the context of position reporting. The display panel must support the use of text as well, both overlayed on a digital map. The software supporting this map must have the capability to isolate a given terrain feature (such as all rivers, all slopes greater than 60%, all highways, and so on), in order to permit terrain, maneuver, and line of sight analysis. The use of menus to assist in the logical arrangement and prompting of ideas is mandatory.. This will be most functional if combined with a scrolling and zooming capability.

B: SUMMARY

BMS as a whole, as summarized here, will support the battlefield decision-making process, and will shorten the decision-making cycle by providing accurate information to leaders. Compressing this time will allow U. S. Forces to execute correct battlefield decisions earlier than the current system does, and thereby maintain the control of the battlefield. The following chapters will discuss the methodology which framed the author's research, and will ultimately demonstrate the pay-off (in terms of reducing confusion, contributing to the proper interpretation and execution of commands, and saving lives) which BMS is capable of providing.

IV. METHODOLOGY

A. INTRODUCTION

This chapter describes the methods and strategies used in conducting our research to accomplish the following principal objectives:

1. Develop a methodology for the efficient use of the communications tapes in research and analytical efforts.
2. Determine the data bit and data bit rate required to support passage of company level tactical information within a Battalion command and control system.
3. Given any processor, with known capabilities, and BMS's known minimum required data bit rate, project estimate the reliability of the system during a high intensity tactical situation (projected peak message traffic).
4. Project future issues and implications that may arise from BMS.

The introduction of BMS has generated several studies focusing on the initial requirements for the system. While the studies have been comprehensive, they have generally been limited in scope to how we, doctrinally, want to fight the next battle, rather than how we, realistically, will fight the next battle. In other words, the studies have a built in artificiality that may hide some of the operational needs of BMS, for example, the ability to compensate for untrained operators or an unplanned event occurs on the battlefield, among others. If this was the case, where analysis of the requirements for BMS focuses on solely the doctrinal issues involved, then BMS may not be the robust, comprehensive, facile tool it was conceived to be. It would appear obvious that any setbacks on the battlefield involving or incriminating BMS will ultimately result in nonacceptance of such a revolutionary system at the Battalion and below, where reliability, accuracy and timeliness are critical. However, augmenting current doctrinally-focused studies with more realistic analyses will yield a smoother transition for BMS and a better understanding of the requirements, since it will be more compatible to our present command and control configuration. More specifically, by focusing the efforts on the maximum data bit and data bit rate currently required for passage of tactical information at Battalion and below, the authors attempted to define minimum transmission requirements for BMS. This was the basis for the authors' methodology.

1. Command and Control in the AirLand Battle

The AirLand Battle will be conducted at a greatly accelerated pace, maximizing the lethality of our combat systems. This necessitates split-second response to orders and fast, violent execution. The commander must make his decisions based upon his ability to see the battlefield. This involves not only the physical ability to see the point of main effort, but also the use of intelligence preparation of the battlefield and accurate information gained from timely reports from both lower and higher echelon reporting units. The planning and execution cycle must be accelerated so the enemy continually finds himself attempting to react to new offensive operations against his flanks and rear. The challenge therefore was to streamline command and control procedures to anticipate and execute immediately.

Command and control, in general, must be capable of handling the demands of more sophisticated weapons, new communications devices, more flexible and mobile tactics, new terms of reference, and new organizational structures. The command and control process is the method used to make and implement tactical decisions. Each time information requiring some action was received, the commander goes through a decision-making process. He collects and analyzes information, decides what to do, organizes his force to do it, orders someone to do it, and then supervises the execution of the decision. Thus, decision-making is a dynamic, goal-oriented, repetitive cycle detailed in the troop leading procedures. When time is critical--for instance, after the operation has begun--the commander will use warning and fragmentary orders almost exclusively. Once he recognizes an opportunity to exploit the success of a subordinate or take advantage of an enemy vulnerability, he must make a decision and quickly instruct his subordinates. The command and control process must discriminate, from the flood of information available, those elements essential to the commander to enable him to make these timely decisions. The process must provide the means to collect, collate, and provide information to the commander rapidly; the commander must work with as near real-time information as possible. The process must function with such efficiency, accuracy, and dispatch that the information, decision, action, follow-up cycle works faster that that of the enemy.[14]

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[14] Much of the preceding is taken from *FC 71-6: Battalion and Brigade Command and Control*, U.S. Army Infantry School, Ft. Benning, GA, 1 March 1985, and from *Command And Control Of The Maneuver Heavy Force In The AirLand Battle*, U.S. Army Armor School, Ft. Knox, KY, 7 January 1986.

2. Battlefield Management System in the AirLand Battle

One way that the U. S. Army can improve command and control is to exploit the technological advantage we enjoy in the area of computer systems. This technology can speed the distribution and processing of information so that decision-makers can make better, quicker decisions. BMS will be designed to accomplish this. The battalion command group is one of the most flexible and dynamic of the organizations on the battlefield, because it is the lowest level at which a staff exists to provide a broad base of support to itself and subordinates. At Battalion and below, computer technology can provide key personnel with the time and tools to think, plan, decide, coordinate and execute faster than the enemy. Until recently, there was little effort to infuse new computer technology at the Battalion and below; most battlefield management research has been directed towards Division and Corps. For these reasons, the project began with a study of maneuver battalion requirements, specifically, the authors concentrated on a typical Armor Task Force and a Mechanized Infantry Task Force in simulated combat at NTC.

Currently, it is the authors opinions that the AirLand Battle is not completely implemented nor comprehensively practiced in the field. This is due in part to the lack of fielded systems to support the more aggressive aspects of the associated tactics. Part of the infusion of technology to the battlefield includes the implementation and fielding of BMS. For it to be introduced now and be readily accepted, it must not only meet current requirements, but also maintain flexibility in order to adjust to growing needs as the AirLand Battle concept progresses and is fully put to use. A primary design goal of BMS was to develop a system based on a full understanding of the needs of its operators and to provide a system that would enhance command and control, communications, surveillance, and fire distribution while reducing crew workload, manual reporting functions, reporting time, time on the radio, maintenance time, administrative chores, and associated stress. A key element in BMS is its reliability. The research was aimed at enhancing reliability by quantifying a minimum acceptable bound on the data bit derived from voice communications using, largely, unformatted reports, and from formatted doctrinal reports and an associated data bit rate required for a system such as BMS. In turn, the evaluation of these data elements will provide flexibility in the system by reducing digital message transmission error rates and facilitating input into formatted messages imbedded in the system's memory, among others.

B. RESEARCH AND ANALYSIS PHASES

1. Overview

A major source of data for research and development of lessons learned was the communications recordings made during an actual training exercise conducted at NTC. Researchers believe that the quantity and quality of the radio communications recordings are sufficient for research and battlefield-level analysis. The tapes alone provide a data base that holds significant potential for useful research and are relevant to understanding leadership and command and control processes on a fluid, highly dispersed battlefield. When combined with data from other sources, especially the associated digital data tapes, the tapes offer research opportunities that could broaden the scope of current efforts and add many new ones. In fact, the added detail contained in the communications tapes and the perspectives their data provide are essential to a full understanding of battle play at NTC. It would be a serious mistake to ignore this rich source of insight and understanding [Ref. 23: p. 45].

We limited the scope of our research efforts to determining the data bit and data bit rates required to support passage of company level tactical information within a battalion command and control system using as the basis for our evaluation the actual voice recordings of two Task Forces in (simulated) combat. After defining the scope, the research proceeded in three distinct phases. The first phase, *Preparation*, enabled us to understand how radio voice communications were recorded at NTC, determine which documents and data sets would be required to monitor the recordings in an intelligent way, assemble those documents and data in usable formats, examine the communications tapes available for this project, and to develop a sampling plan and method.

In the second phase, *Data Collection*, the segments of recordings were monitored and information was collected that was necessary to determine the minimum data bit and data bit rate. Interviews were conducted with project managers associated with BMS, in order to define design goals and objectives of the system. In addition, documents were obtained that discussed the purpose of BMS, including both past and current attempts oriented towards its development. References were obtained that provided the technical guidance necessary to generate the analytical formulas that converted the raw data derived from the tapes into useful architectural information.

In the third phase, *Data Analysis*, the contents of the sampled segments of tape were analyzed to determine message start and stop times, message flow, message content, number of characters per message, length (in seconds) of each message, type report, message format, and the activity phase of the unit at the time the message was initiated. This data was then entered into a database for manipulation. The final process was to interpret the information obtained from the database and apply it to BMS.[15]

2. Preparation: National Training Center

a. Recording

Acquiring an understanding of the recording procedures used at the NTC was the first step in preparing to use the recorded voice communications. Those procedures are outlined in Reference 23, pages 2 - 13.

b. Source Documents and Data Sets

After acquiring an understanding of general communications procedures at NTC, the next step in preparing to use the tapes was to locate and assemble the necessary documents and data sets for each training rotation (or cycle) of interest.

Table 1 (see below) contains a list of those items required to catalog and index the communications tapes and to monitor the transmission activities intelligently. These items were necessary to accurately relate the tapes to specific mission segments contained in the NTC digital data tapes, and to provide essential data concerning task organization, scheme of maneuver, and radio callsigns. One or more of these items assumed a greater or lessor importance depending on the nature of the research or analytical task. For our examination of one rotation (or training cycle), the three idems identified below was absolutely essential.

(1) *A Communications and Electronics Operating Instructions (CEOI).* One for each training rotation (or cycle) examined. This was a source document from which station call signs and player suffixes could be extracted.

(2) *AMPEX Radio Voice Communications Tape Reels.* One for each rotation. This provided voice transmissions on most friendly nets from company through division and most of the control nets.

(3) *National Training Center Task Force History Catalog Report.* This report lists the mission segments contained in the National Training Center Digital Data Tapes. It enabled us to locate two identical missions, i.e., Hasty Attack, for two different task forces.

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[15] See Chapter Six for a more detailed discussion and description of the data, and Chapter Seven for a discussion of the analysis of the data.

The other items listed in the afore mentioned study would have been useful in conducting a more in-depth battle analysis.

The communication tapes were used on equipment resident at the U. S. Army Research Institute's Monterey Field Unit laboratory. This provided an easily accessible means of working with the tapes to extract the data necessary for analysis.

TABLE 1

SOURCE DOCUMENTS AND DATA SETS REQUIRED FOR MONITORING TAPES

- Communications and Electronics Operating Instructions (CEOI)
- AMPEX Radio Voice Communications Tape Reels
- National Training Center Task Force History Catalog Report

c. Formatting Information Aids

Once the required source documents were located and assembled, it was then necessary to extract and format relevant data into indexes, maps, and directories that allowed us to select and monitor segments for specific purposes. A discussion of the seven most important aids developed for this research project is provided below.

(1) *Aid 1--Mission Indices.* One for each Task Force which provides mission segment identification numbers, mission type, segment start time and date, segment end time and date, and segment duration. These data were extracted from the National Training Center Task Force History Catalog Report (generated from National Training Center Digital Data Tapes), and allowed us to select specific tactical missions for study and key those to date/time dimensions and segment numbers. The date/time dimensions were required to select appropriate communications tape reels. The specifices for this collection effort are clearly detailed in Reference 23.

(2) *Aid 2--Tape Reel Maps.* One for each Task Force which displays graphically the contents of each tape reel in date/time dimensions. These data were extracted from the labels on each of the tape reel containers. Reels marked with the letter "G" contain transmissions from Granite Mountain. Those marked with "T" contain transmissions from Tiefort Mountain. With date/time dimensions taken from

a Mission Index, tape reel information arrayed in this fashion enables one to select reels for specific mission segments as shown in Reference 23.

(3) *Aid 3--VHF Receiver Channel Assignment Maps.* One for the rotation which lists channel assignments for each net and each day of the exercise. Data for these maps were taken from daily communication log sheets prepared in the central control facility at NTC. The channel numbers correspond to the numbered receivers on Granite Mountain. This information was essential in locating a specific net/channel for monitoring as shown in Reference 23.

(4) *Aid 4--Mission Directories.* One for each mission examined. The directory provides a task organization, initial maneuver graphics, and a communications key for the mission. This was the minimum data set required to place a tactical mission in context and provides information concerning player units and radio callsigns. The task organization was taken from the summary statistical data in the National Training Center Digital Data Tapes as displayed on screen. The maneuver graphics were traced from a 1:100,00 scale map. The unit symbol locations were approximate as of mission start time. Communications Key data were from the CEOI used during the rotation as shown in Reference 23.

(5) *Aid 5--Sampling Plan and Method.* With the information aids developed, one may then select tape segments and monitor for specific purposes. Reference 23 contains a schematic of the sampling plan that guided the current research effort. At this point it was necessary to establish the sample mission event and sample size. Our selection of the Hasty Attack as the mission event, was based on our experience that an unplanned, dynamic event on the battlefield would generate a peak transmission period. This was further substantiated in Reference 23, page 20. Using the 40-channel communications tapes for Rotation 1, the Hasty Attack mission was examined for two units. The first unit was a Mechanized Infantry Task Force. The duration of the evaluation was one and a half hours. In this particular rotation, the Hasty Attack was conducted shortly after the arrival of the unit at NTC. The second unit was an Armor Task Force. This duration was three hours and was conducted towards the end of the unit's rotation at NTC. This provided a sampling of units both before and after the 'learning curve' effect. An initial approach to selecting a start time for the evaluation was to simply monitor the Scout/Intel net for passage of lines and then identify the first indications that the unit was observed by enemy forces. Shortly thereafter, friendly forces no longer controlled the battlefield, and it was at this

time that the taping began. The stop time occurred when the unit's actions were more setpiece and deliberate, and the number of transmissions decreased as a result of the unit's ability to organize its assets into a more controlled attack. The authors' desire in both instances was to capture the uncertainty, hesitancy, and confusion on the battlefield at a time when the reporting of information would be the greatest, where the need for accurate, timely information would be the most critical, and where a system like BMS might, in comparison, provide the greatest pay off for command and control.

(6) *Aid 6--Data Record Sheet.* One for each frequency monitored. This form provided the general mapping of what actions were taking place and the start and stop times of each tape segment for a given frequency as shown in Appendix A, Figure A.1.

(7) *Aid 7--Data Worksheet/Evaluation Form.* Each section on the form was designed to hold one message, however the authors' experience was such that many messages required the use of more than one block in order to transcribe the total message. Each message may consist of more than one transmission. Each segment on the form provided areas to annotate counts and observations taken from the segments of tapes. This form provided the raw data that was used to build the database as shown in Appendix A, Figure A.2.

d. Ft. Knox Land Battle Test Bed

In order to establish and broaden our research base, two fact-finding trips were taken to Ft. Knox's Land Battle Test Bed. During these trips, we had the opportunity to discuss previous attempts to identify BMS requirements and to understand, fully, the impact of BMS on the modern battlefield. In addition, we were able to review on hand documentation that provided the historical progress of BMS from concept to present day. This information proved invaluable in supporting our research attempt to identify realistic communication requirements for BMS. As indicated by the studies, there have been no previous attempts to identify the data bit and data bit rate required for passage of tactical information on the battlefield at the Battalion-level and below, using data from current capabilities, and this is the focus of this present work.

3. Data Collection

a. Equipment

A single 40-channel Veritrac Model 5000 Dictaphone Voice Playback System was used to monitor and record selected segments of recorded radio voice communications. The system contains two playback decks, each equipped with a foot pedal control device that provides start, stop, rewind, and fast-forward options. A control panel on each deck contains 40 push-button channel selectors (numbered one through 40), to allow selection of the Tiefort Mountain channels, and a Volume Unit (VU) light indicator with a scale of -20 VU to +5 VU. Additional numerical labels (numbered 41 through 80) were added to each bank of 40 channel selectors to allow selection of the Granite Mountain channels on either deck. Each deck can accommodate a single tape reel of recorded voice communications; only one deck could be used at a time.. A single time code display panel shows the date/time code data recorded on the tapes. From one to 40 channels may be monitored simultaneously with or without the use of a headset. In order to facilitate player debriefing, an entire mission event will be recorded at NTC on several different tapes. This feature necessitated the use of a VHS recorder in order to record skewed segments of the Hasty Attack and combine them into one continuous flow of information and to retain the transmissions for future data reduction efforts. [Ref. 23].

b. Collection Procedures and Record Categories

The two members of the team alternated in recording the sample selections. Then, during each sampling period, one member monitored all activity, recorded his initial observations of the mission element on a separate data record sheet (see Appendix A, Figure A.1). The unit of activity on which observations were made was the single message. For the purposes of this study, a message may contain one or more transmissions. A transmission was defined as that acoustical activity resulting when a radio microphone was keyed, an operator talks, and the microphone key was released. The standards for capturing a recorded observation was covered in Reference 23.

4. Data Analysis

a. Tape Reduction

During the Preparation phase, the authors were able to coordinate with Ft. Knox's Data Reduction Center to convert our tape recordings into useful raw data. The Data Reduction Center provided a professional and consistent approach to extracting the data. They did this on the Data Worksheet (see Appendix A, Figure A.2.). The form was developed to capture those elements of the tape we thought would be most valuable in our research. Each segment of the form was designed to record the data for each complete message.[16] In addition, each segment was broken down into two parts. Part one was Callsigns and part two was Messages. The purpose of this configuration was to separate messages or transmissions which contained message content from those that did not. An example would be where a calling station may make several attempts to contact another station without success. The message may contain one or more transmissions. The total message length, the number of transmissions per message, and the number of characters per transmission, were recorded on an informal supplemental data collection sheet, provided by the Data Reduction Center.

b. *Database*

Once the data reduction process was complete, the authors were able to identify specific data elements that could be configured into a database. The data was critical, but in its present form, it provided no productive use. However, within a database structure, several operations could be performed that could transfer the raw data into useful information that would provide input to the endeavor to determine the voice requirements for BMS.[17] Once the database structure was established, a program was developed that would allow the user to update the database with an entirely new set of data or perform several operations with ease in order to extract pertinent information for any future analysis. This may be beneficial if an attempt was made to validate these results with more recent data available from NTC, as might be recommended when the platoon level tapes that were not available for our research become available.

c. *Analysis*

As mentioned previously, the database provided the tool to manipulate the raw data into useful information necessary to determine the voice requirements for BMS. This information provided the inputs to the authors' effort to determine the digital requirements for BMS.[18] A research goal was to identify the peak stress points on the current system and to evaluate those maximums against a computerized system such as BMS to determine the impact that BMS may have on the modern battlefield. To achieve the peak stress points, the authors maximized the output of our queries.

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[16] See Chapter Six for a more detailed discussion on the different attributes chosen for the data collection effort.

[17] See Chapter Seven for a more detailed explanation of this process and the results generated.

[18] See Chapter Eight for a more detailed discussion of this process.

Prior to any attempt to determine the digital requirements of a system, it was necessary to establish a profile of the voice requirements for the selected sample. The first step was to identify an unplanned, spontaneous event which was discussed earlier. Next, it was necessary to identify the maximum characteristics for each frequency. Then, a comparison of the seven frequencies was made for the maximum output for each category considered. By analyzing the sample size for the maximums of the maximums, the highest level of stress on the communications systems was determined. The last step was to digitize the voice requirements and determine the minimum acceptable bound on the performance specifications necessary for a processor handling digital data.

V. ASSUMPTIONS AND LIMITATIONS

A. INTRODUCTION

This research was conducted to, primarily, identify a data bit and a data bit rate requirement for the passage of tactical information at the company leval and below. In order to provide both control and direction to the processes involved, it is necessary to recognize the assumptions that were made. These assumptions and their impact on the research will be outlined in this chapter. As a result of these assumptions, there are certain limitations that can be associated with the selection of a particular course of action and its impact upon our conclusions. These limitations will also be discussed for the purpose of recognizing their bearing on the research.

B. ASSUMPTIONS

Each assumption will be identified and discussed with the phase with which it is associated.

1. Preparation

a. Doctrine

The authors assumed that no significant changes in mechanized doctrine and tactics will occur between now and the final phase of fielding for BMS. The AirLand Battle doctrine is considered the most recent development in this area and it provides the basis for the technological requirements for BMS.

b. Research and Development

The authors assumed that current systems and munitions in development will be fielded as scheduled and will meet projected performance characteristics. Most applicable to this study is the SINCGARS (Single Channel Ground and Airborne Radio System) system that is projected for Army-wide use and replacement of the current family of FM radios which must, therefore, be compatible with BMS.

c. Communication

(1) *Configuration.* The communication system and command and control configuration of the non-BMS equipped units analyzed in our research portrayed the essence of the present command and control process and of the requirements throughout the task force level for any similarly structured organization.

(2) *Continued Use of Existing Radio System.* Existing FM radios will continue to be used until SINCGARS is fielded. This assumption was necessary since the units which provided us the data base communicated via FM voice and it is estimated that BMS will be fielded initially with existing FM systems.[19]

d. Command and Control

Improved quality and flow of critical information enhances the command and control processes, resulting in a more combat effective unit.

e. Unit

Certain complementary data, such as radio operator training and experience, radio maintenance status, and terrain profiles, represent the norms. The authors also assumed that the sampled units' tactical operating procedures are representative of a cross section of U. S. Army units and they provide a valid model upon which to establish the minimum requirements for BMS.

f. Mission Event

The authors assumed that units undergoing the effects of a nuclear, biological, or chemical weapons attack would not be suitable for evaluation. This has to do with the fact that these catastrophes are highly unpredictable and would yield a wide disparity of results dependent upon several unknown and undefinable variables. Therefore, the Hasty Attack was considered to be the most unplanned, confusing, spontaneous tactical event possible from the selection of mission events available on the tapes. The underlying assumption is that the Hasty Attack would provide a greater number of transmissions per unit of time for analysis (i.e., it would stress the existing communications system the most and provide the best model to use as a baseline for BMS), as the commander commits his forces to meet an ill-defined enemy threat. Other tactical scenarios, such as the Deliberate Attack and Deliberate Defense were, in the authors' opinion, more structured and involved more pre-planning, followed by careful execution of a detailed battle plan. Given the unplanned nature of a Hasty Attack and the requirement for accurate information to be passed quickly both up and down the chain of command, the authors assumed it would provide the most readily-accessible example of the limitations of FM voice single-channel communications. This supposition was further validated in Reference 23, page 20.

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[19] The troubles that TACFIRE had with using the current radio system, i.e., the trouble of mixing new technology and old technology as described above in Chapter Two, should alert the developers of BMS to potential problems which can be planned for and overcome before BMS is fielded.

g. Research Team

Both members of the research team are U. S. Army Combat Arms Officers and have ample troop level command, in addition to having held positions on a Battalion level staff in maneuver units. This provided a basis for interpretations, decisions, and conclusions to be made in circumstances where neither the voice transmissions nor the video digital tapes provided a clear picture of the real units' functions. These kinds of decisions, based upon the authors' experience and tactical knowledge, was most often made in the area of speculating on the units' activity phase, i.e., in place, moving, contact, or attacking, which are side issues of the research.

2. Data Collection

a. Tapes

(1) *The Impact Of Garble and Interference.* Transmissions with garble or interference and bleed over from other frequencies do not necessarily represent potentially useful information that is lost. This 'contaminated data' indicates the type and relative amount of extraneous and distracting activity which exists in our current FM voice command and control system. Although it was the authors' intent to omit these incidents from the actual data and exclude it from the database from which the bit and bit rate requirements are determined, they were helpful in developing conclusions and recommendations concerning the reliability of BMS as compared with present FM voice communications.

(2) *Choosing Start And Stop Times.* Start and stop recording times were selected in an attempt to capture the peak transmission periods by the units involved. Given the unplanned, and dynamic nature of the Hasty Attack, we strived to isolate this portion of the battle by identifying start and stop times based upon the authors' own experience, their tactical knowledge of the situation, and by the observable increase in radio transmissions by the units involved. The start times were established by monitoring the Scout frequency as the unit conducted its passage of lines and then identifying the first indications that the unit was observed by enemy forces. Once friendly forces came under fire, and it was obvious they no longer controlled the battlefield, the taping sequence began. The stop times were dictated by the either the controller stopping the mission event because of the failure of the unit to successfully

execute its mission, or when the units' actions were more set piece and deliberate, and the number of transmissions decreased as a result of the units' ability to organize its assets into a more controlled attack. Both scenarios provided a fertile source of information; the former precisely, because the unit never regained control of the battlefield and stressed its command and control systems in the process. The latter because it was able to successfully execute its mission and did stress its communication system in doing so. The noticeable decrease in the number of transmissions in the second Task Force as the battle became more deliberate supports the authors' initial assumption that the Hasty Attack (as opposed to a Deliberate Attack) offered a viable tactical scenario from which to derive the requirements for BMS.

3. Data Analysis

a. Tapes

(1) *The Use of Complete Messages.* A complete message normally consists of several transmissions. This allowed the authors to evaluate the transmission information content and separate those attempts to merely establish contact with another element from those transmissions containing information or directives which bear directly up on the outcome of the Hasty Attack.

(2) *Content Classification.* Each transmission containing such content can be classified according to one of the various standard U. S. Army reports. Those that could not were presumed to be identified with a unit level report established by the local commander, or the context of the content was not sufficient to enable the authors to determine which report was being (or could have been) used. The grouping of reports into identifiable formats provided the authors with the ability to determine the data bit required to transmit tactical information on the battlefield in a timely and reliable manner.

b. Data Reduction

(1) *Chronological Sequencing.* All recorded times represent continuous elapsed times from the start of the tape. This allowed the authors to easily reference locations within the tapes for further study as needed. In addition, it helped separate the real time of the event, its own date-time-group, from the analysis, and ensured that the identity of the units at NTC is protected.

(2) *Equipment Requirements.* There was no unique apparatus employed for data reduction tasks, however, several assumptions were associated with this task for simplification. In order to provide consistency, they are:

- messages were transcribed manually without a loss of content

- 'uh's' and 'ah's' were not counted as characters, but the time delay for these comments were included
- all numbers were counted as digits, unless used as text to indicate quantity (niner = 9)
- callsigns were counted as words (B27 = Bravo 27 = 8 characters)
- blanks between words were included as part of message content
- only complete messages were used
- unless indicated by the proword 'Break', a transmission was considered to be continuous when in reality the element talking may have unkeyed the microphone without using the appropriate proword

The impact of the above assumptions may result in a lower character per second transmission characteristic than may actually be occurring, which translates to a lower bit per second requirement for BMS. These assumptions drove the authors to establish a minimum acceptable bound on some architectural characteristics for BMS, not maximum acceptable bounds. The assumptions do not violate this goal. Where parts of a message could not be transcribed, due to garble or interference, those messages were not counted. However, as mentioned previously, these messages were acknowledged as important to the overall research effort, especially in the conclusions and recommendations regarding the required reliability of BMS.

C. LIMITATIONS

As stated in the introduction, certain limitations identified throughout our research will be identified and discussed with the phase in which it was observed. A detailed discussion of the limitation and its impact follows.

1. Preparation

a. Doctrine

(1) *Combined Arms.* Some aspects of the combined arms concept could not be adequately portrayed in the data collection effort. Examples include the use of Tactical Air and the role played by Attack Helicopters. This was due primarily to the nonavailability of tapes of those units. It was assumed, however, that in determining baseline requirements from the data available, that the information requirements for these units will be provided for as well.

(2) *Combat Service Support.* Additionally, the requirements to support the Combat Service Support (CSS) functions for both Task Forces were not captured on tape due to the selection of the Hasty Attack as the mission element for study. It was assumed, however, that in determining baseline requirements from the data available, that the information requirements for these units will be provided for as well.

b. Unit

(1) *Limited Initial Choice.* The authors had only two Battalion Task Forces from which to choose. Other tapes were not available for use so the sample size was limited from the outset by the fact that the utilization of NTC tapes was a new concept, and other tapes archived at either Ft. Leavenworth or Ft. Irwin were not available for use. However, from these two task forces the authors selected nearly 500 complete radio messages from which to determine the minimum BMS requirements, and believe that this is a sufficient base.[20]

(2) *H-Series Table of Organization and Equipment (TO&E).* The two Task Forces available for use were organized under the H-series TO&E, whereas BMS is expected to be fielded within the J-series TO&E. This circumstance further validates the authors' approach to derive a lower bound on the performance standards for BMS because the J-series TO&E vehicle density is greater than that of the H-series, so the information flow requirements will be correspondingly greater also.

c. Tapes

The utilization of the tapes produced at NTC for research effort is an idea that has not been previously implemented. Therefore, only one iteration of tapes were available at the time and no technique was established to monitor transmissions from platoon to company level, restricting the sample size even further. Future iterations will continue to be taped and will provide a broader data base for analysis, as is suggested in Reference 23.

2. Data Collection

a. Tapes

In many instances, based upon content and sequencing of certain transmissions, it could be inferred that a person who could be heard and understood was talking to a second person who could not be heard. In some cases, there were noise and/or light signals to indicate the second person's activity, but in many cases, there were no audible indications that a second person was talking. According to Reference 23, pages 27 and following, only sixty-two percent of transmissions occurring in the training area were either readable or partially readable, and the other thirty-eight percent were, therefore, not suitable for analysis. This limitation could detract from a detailed content analysis aimed at modeling information flow, but did not significantly hinder the authors' ability to determine a minimum data bit requirement and a data bit rate, based upon the requirement as expressed in the tapes of the voice communications.

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[20] See the verification of this in the results described below in Chapter Seven.

b. Human Factors

There was limited knowledge of the true situation or conditions, since unit operations orders, commander's concepts, maps, and so on weren't available. Neither were the After Action Reviews, i.e., video and digital displays generated by NTC, available to assist in this assessment. The impact was a lack of perspective on the attitudes, emotional factors, or level of maintenance of the unit. Other factors, such as the MOPP level, the number of operational vehicles and radios, and the amount of fatigue, could also not be known by the authors. However, based upon the flow of information and other factors recorded in the tapes, these unknowns did not prevent some judgement from being made concerning the characteristics of command and control elements of the units. For a detailed discussion on the possible impact of each of these factors, and others, see Reference 24.

3. Data Analysis

a. Sample Size

Of the total number of messages recorded (1,194), only 479 of them met the standards of clarity and other measurable message characteristics requisite for inclusion in the database. The two fundamental characteristics (other than message clarity) were the number of characters in the message and the total message time. This means, then, that approximately forty percent of all recorded messages were suitable for use in this thesis. The standards established early on, however, guarantee that the results obtained from this analysis will be based upon valid data, and not spurious estimates of what is transmitted during periods of garble or interference. The underlying assumption is that what was used does not differ in characteristics from what was not used, and that a larger sample size would only validate the conclusions derived from the existing sample.

b. Queries

As noted below in Chapter Six, the data collected will support a plethora of queries far outside the focus of this thesis. As a result, the authors had to limit themselves to answering the basic 'who talks to whom, when, and what do they say' type queries, and had to ignore the other questions capable of being answered. Retaining the focus of the thesis was a prerequisite to it getting done.

c. *Human Factors*

As noted above, the authors did not have a clear picture of the human side of the battlefield. Undoubtedly, some of these factors contributed to the characteristics of the messages analyzed, i.e., fatigue and MOPP level may have necessitated the repetition of the same message several times which would have been clearly understood and properly executed under less physiologically or psychologically demanding circumstances. This creates the situation wherein the human element may have artificially inflated the actual performance requirements for the system. However, the assumption which safeguards this reality is that even with BMS in place the same human factors will continue to adversely affect the requirements for the communications system, and the design for BMS should incorporate these requirements from the outset.

VI. DESCRIPTION OF DATA

A. INTRODUCTION

Having described the methodology and the assumptions and limitations which framed the research effort, it is now possible to describe the raw data obtained from the recordings of FM voice radio traffic from two Battalion Task Forces in training at the NTC. Defining the information requirements to support the passage of company level tactical operations within a Battalion under different tactical circumstances is a critical need, and is vital to quantifying the requirements for BMS. As will be evident during the course of the data description which follows, an abundance of other questions concerning issues in communication, information architecture on the battlefield, and command and control other than the ones the authors focused on can be answered from the same source tapes.

B. DATA COLLECTION PROCESS

Having selected the Hasty Attack as the mission element to support the determination of the minimum requirements for BMS, the authors isolated and recorded the unedited voice traffic of selected radio nets which operated within the Battalion command and control structure of the units at NTC. The attempt was to capture the traffic flow in and out of the Company level net, so all frequencies generally associated with the Company net (i.e., on either the Battalion or the Platoon nets) were analyzed for amount of traffic flow and degree of stress placed on the communication system itself. Priority of consideration was given to units in the lead of the Hasty Attack, whether specifically within the operational concern of the Company net or not. As it turned out, both Task Forces conducted a passage of lines through friendly forces, passed their Scouts through first, and then deployed their lead companies once the Scouts had established contact and had developed the situation. The result was that all units directly involved in fighting the battle, in reporting and providing information to decision-makers, and in relaying decisions to subordinates for execution, were within the desired scope and were applicable to the analysis.

As noted previously, recordings of the Platoon level units were not available, so a number of different Company level nets were recorded in an attempt to capture the Company-Platoon relationship as heard on the Company frequency. However, the

Combat Support elements nets (Field Artillery, Mortars, Engineers) as well as the Combat Service Support net (the Battalion Task Force Administrative/Logistical net) were recorded and evaluated. The attempt was to analyze the entire spectrum of operational requirements in this analysis of the baseline requirements for BMS.

The number and type of different nets recorded initially is provided below in Table 2. These 16 nets were recorded on seven VHS tapes and were provided to the Data Reduction Cell at the Armored and Engineer Board, Fort Knox, Kentucky, for the Data Reduction process.

TABLE 2
NETS INITIALLY RECORDED

Net Recorded	Task Force 1	Task Force 2
Battalion Command	One	One
Task Force Admin/Log	One	One
Scouts/Intelligence	One	One
Company Command	Two	Three
Vulcan/ADA	One	Zero
Engineer	Zero	One
Fire Direction Control	Two	One
TOTAL	Eight	Eight

C. DATA REDUCTION PROCESS

The Data Reduction process consisted of transcribing the seven VHS tapes by hand onto the Data Worksheet/Evaluation Form (see Appendix A, Figure A.2) in order to provide the information necessary in a format compatible with eventual entry into a database. Having the data in a database made it suitable for manipulating and comparing otherwise scattered and unrelated data in order to analyze it and establish the baseline requirements for BMS. The Data Worksheet/Evaluation Form measured the time involved in establishing contact, the time involved in exchanging the requested necessary information, determining who was talking to whom, transcribing the content of the message verbatim onto the Data Worksheet/Evaluation Form, analyzing the message to determine whether or not it was or could be identified as a standard (formatted) report, and determining what the unit was doing at the time the radio traffic was sent. These categories were basic to understanding the information architecture of the units in training (who talks to whom, when, and what do they say). A detailed discussion of the data elements of the form is provided below. The data elements (attributes) are discussed under the two major headings by which they are organized on the Evaluation Form, namely, under Callsign Data Elements and Message Data Elements.

1. Callsign Data Elements

a. Time Initiated

The timing of a transmission begins (relative to the start of the tape) when the calling station initiates his attempt(s) to contact someone else.

b. Calling Callsign

The callsign of the station initiating the call is recorded here.

c. Called Callsign

The callsign of the station being contacted is recorded here.

d. Time Completed

This subportion of the overall message time is recorded here and is defined as that moment when the called station acknowledges the call, or when the called station cannot be reached and the calling station ceases his attempt(s). This provides a measure of the amount of time spent just establishing (or trying to establish) a positive communications link between two elements on the battlefield.

e. Message Hierarchy

This depicts the message flow between the two communicating stations. It is determined by the flow of the content/information pertinent to the battle, and not necessarily by who initiates the call. The attempt here is to measure the requirement for information at any given level of command based upon the amount of information provided to it, whether provided as a result of a request, or not. When considered in addition to who initiates the call, it may provide an initial analysis of the impact which a particular style of leadership (i.e., personality) may have upon the communications net (and his subordinates) through his usage of the net.

2. Messages Data Elements

a. Time Message Completed

This is the time when the connection between the two elements is broken. It is usually recognized by the presence of the proword 'Out', but not necessarily so.

b. Total Message Length

This is the computed time duration of the total message. It represents the difference (in seconds) between the Time Initiated and the Time Message Completed data elements.

c. Characters Per Message

This consists of an accurate count of the number of characters present in the complete message, from the time of initiation to the time of completion. See the assumptions regarding the counting of characters provided above in Chapter Five. Recognizing that BMS will ultimately send messages digitally, this total count will quantify the digital voice requirements.

d. Type Of Report

Messages were categorized according to the type of report which best reflects the content of the message. This classification will quantify and help determine the types of reports utilized for battlefield information reporting in relation to the units activity (see below), and should provide some parameters on which reports should be imbedded in BMS. The numbers here may also reflect the degree of control which a given superior exercises over his subordinates, so that a high occurance of Fragmentary Orders (FRAGOs) as compared to Spot Reports may be related to the leadership style of the superior and his degree of control, but this and related issues are outside of the focus of this work.

e. Message Format

This block was first used to record whether or not the message sent was sent in a recognizable message format, or not. However, after the first three frequencies were evaluated, it was obvious that very few formally structured messages were being sent. A quick check of the remaining nets confirmed this phenomenon, so the meaning and purpose of the content of the block began to be in doubt. It was nothing new to learn that almost no obviously formatted messages were sent. Therefore, a change in the meaning of the entry in this block was necessary if this block was to provide any useful information. Ultimately, this block was used to record the occurrence of proper Radio-Telephone (RTO) procedures, and to record whether or not the message sent COULD have been sent in a structured format. Thus, if proper RTO procedures were utilized, and the content of the message could have been sent in a formatted, standardized message, it was recorded as a 'yes'.

f. Activity Phase

This is a subjective analysis of the activity of the unit (i.e., company, or platoon, but NOT individual vehicle) at the callsign level in relation to the overall mission. The unit was categorized as either Moving, In Contact with the enemy (for the first time), Attacking, or In Position. The accuracy of the data in this field is less precise, less strict, because the analysis of the activity of the unit being monitored was based upon the content and context of the messages, and the authors' own understanding of the specific tactical operation and maneuver warfare in general. The tools to provide an unquestionably accurate analysis of this data element do not yet exist. Nonetheless, the data entries are considered to be valid and are sufficiently general in nature that a rough idea of the relationship between a unit's activity and the number and type of information it sends (or needs) can be established.

A summary of the raw data content (the values) for each of the seven frequencies analyzed is provided in Appendix B.

D. DATABASE STRUCTURE

From the data provided by the Data Reduction cell at Ft. Knox, the authors utilized six frequencies which provided the greatest number of readable transmissions per mission, and retained, for comparative purposes, the data from one of the least frequently used nets. All seven were entered into our database. The seven nets included one Battalion Task Force Scout net, one Battalion Command net, one Field Artillery Battalion (i.e., Fire Direction Control) net, and four Company Command nets. The other nets initially taped did not provide the amount of traffic, the frequency of use, nor the amount of stress which the authors considered as prerequisite for use.[21] Structurally, the database is very similar to the Data Worksheet/Evaluation Form, and resulted in a total of 53 data fields for each tape. Each tape was organized into its own database of flat files with the result that one applications program ran equally well on all seven databases. These files are sequential files, representing the chronological flow of information as it occurred on the battlefield. The key to the database is a multivalued key, i.e., a combination of two fields (frequency number and message number, see below) was chosen as the key which would be used to selectively address any single file (message). This key is the determinant for any functional dependencies in the database. That is to say, a multivalued dependency exists between the key and each tuple. A candidate key (the combination of frequency number and time initiated, see below) exists, but was not not chosen. The more logical choice for our purposes was the key identified above. Creating the databases initially involved reading the hard copy Evaluation Forms and reproducing them electronically in the database, with some additional fields added for clarity and ease of manipulation. A discussion of each of the 53 fields follows:

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[21] Unfortunately, neither of the Administrative/Logistical nets reflected the necessary usage and stress requisite for establishing the minimum acceptable standards for BMS. However, it is not unusual for this type of net to be sporadic in use, and its lack of use during the conduct of a Hasty Attack is not uncommon. An interesting study would be to evaluate the stress placed upon the Admin/Log net prior to the outset or following the conclusion of a tactical operation, and to quantify the positive impact BMS will have upon that net's operation and message throughput under those circumstances.

1. **Frequency Number (FREQ_NO)**

This number is assigned to each frequency selected for inclusion in the database. Entries in this field are mandatory and nonchangeable [Ref. 25: p. 220].

2. **Message Number (MSG_NUMBER)**

This number is assigned to each message as the message is heard on the tape. Each message receives its own unique number. When combined with the frequency number, it provides a unique key with which to access any particular message or group of messages for analysis. It was a field three characters wide which required characters for input.

3. **Time Initiated (TIME_INIT)**

Identical with the Evaluation Form described above. It was a field five characters wide which required characters for input. When combined with frequency number above, it provided the candidate key to the database.

4. **Calling Callsign (CALLING_CS)**

Identical with the Evaluation Form described above. It was a field five characters wide which required characters for input.

5. **Called Callsign (CALLED_CS)**

Identical with the Evaluation Form described above. It was a field five characters wide which required characters for input.

6. **Time Completed (CS_COMPL)**

Identical with the Evaluation Form described above. It was a field five characters wide which required characters for input.

7. **Message Hierarchy (MSG_FLOW)**

Identical with the Evaluation Form described above. It was a field three characters wide which required characters for input.

8. **Content (CONTENT)**

The entry in this block was used to record whether or not any information pertinent to the fight of the battle was communicated between the two elements involved. It quantified the number of times actual information was passed versus the number of times spent merely establishing contact with another element on the net. It was used to verify the successful exchange of battlefield information; it quantifies the number of times that a message verification scheme would be useful if provided with BMS. It was a field one character wide which required a character for input.

9. **Time Message Completed (TIME_COMPL)**

Identical with the Evaluation Form described above. It was a field three characters wide which required characters for input.

10. **Total Message Length (TOTAL_TIME)**

Identical with the Evaluation Form described above. It was a field three characters wide which required numeric input. This numeric input was necessary in order to permit the database to automatically sum the contents of this particular field. The summation of the other time related fields above was not of any significance to the thesis, so their fields were structured as character fields.

11. **Characters Per Message (CHAR_MSG)**

Identical with the Evaluation Form described above. It was a field four characters wide which required numeric input.

12. **Type Of Report (TYPE_REPT)**

Identical with the Evaluation Form described above. It was a field three characters wide which required characters for input.

13. **Message Format (MSG_FORMAT)**

Identical with the Evaluation Form described above. It was a field one character wide which required characters for input.

14. **Activity Phase (ACTIVITY)**

Identical with the Evaluation Form described above. It was a field two characters wide which required characters for input.

15. **Number of Characters Per Transmission One (CHAR_XSM1).**

This field recorded the number of characters for the transmission which immediately followed. Although identified above as pertaining to Transmission One, this block was repeated 19 additional times, serving the same purpose for each of the 20 blocks within which individual transmissions comprising a complete message were recorded. It was a field three characters wide which required characters for input.

16. **The Text Of Transmission One (XSM1_TXT)**

This field contained the verbatim transcription of the voice recordings of the units which provided the data for the database. Although identified as pertaining to Transmission One, this block was repeated 19 additional times, serving the same purpose for each of the 20 blocks within which individual transmissions comprising a complete message were recorded. It was a field 190 characters wide which required characters for input.

E. INTERRELATIONAL CONSTRAINTS CONSIDERED

Constraints are limitations on the values the database can have, and of the three basic types of constraints, field constraints have been identified above in the discussion of the subschema view of the data. The other two constraints, intrarecord and interrecord, will be discussed here.

1. Intrarecord Constraints

Because of the chronological nature of the data, there are restrictions on the limits of the values the data can take between fields in the same record. The values recorded for the time the message was initiated must be less than the values recorded for the time the called station responded, which in turn must be less than the values recorded for the time the communication was terminated. Subsequently, the start time for message two must be greater than the end time for message one, so that the start times between messages must be in ascending numerical order. The same argument extends to the relationship between the fields which record the interim time (when the called station acknowledged the call) and the stop time, when the communication ceased. These entries must also be in ascending numeric order.

2. Interrecord Constraints.

The interrecord constraints model the reality of the communication conventions currently in use. That is, a wingman normally talks on the platoon net, and nowhere else. A platoon sergeant normally is capable of talking on either the platoon net or the company net. Thus, values found in the calling and called callsign fields identified above will not appear anywhere else within the database unless they occur on another net through the process of modelling the reality of present communications protocols.

3. Relationship Between Attributes

The start and stop times of any message functionally determine the total message time. This is to say that given the message start and stop times that the message total time can be computed. This relationship holds true throughout the entire database.

Additionally, the number of characters in each transmission, when summed for each transmission in a complete message, functionally determines the number of characters per message. Said another way, if I know the number of characters used in each transmission of a message, I can determine the total number of characters in the message itself by merely summing the subtotals for each transmission. Again, this relationship holds true throughout the entire database.

F. SUMMARY

Each of the database files can be accessed, joined, or otherwise manipulated in order to analyze a particular aspect of the content of the radio traffic, and from the analysis determine the parameters on the requirements for the item under analysis. Access to the database can be accomplished globally (i.e., the entire database can be accessed or searched) or an individual database (i.e., frequency) can be accessed in order to provide a more selective search capability. Typical queries which our database will support far exceed the focus of the thesis, so we have restricted the domain of queries to answering the 'who talks to whom, when, and what do they say' questions.[22]

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[22] There are other ways to sort the data, particularly if an individual aspect of radio communications is under scrutiny. The author's could have grouped the data to answer the basic 'who', 'what', 'when' type questions, in which only four databases would have to be created. The fourth relates to the structure within which the data is collected, and includes fields such as Message Number, Type Report, Format, Activity, Message Length (in time and characters). The other three databases would be set up in order to answer the 'who' type questions, and would include fields such as Message Number (the key), the Calling Callsign, and the Called Callsign. Data grouped around 'what' would include fields such as Message Number, Content, and the Text Of The Transmission. Data grouped around the basic 'when' questions would include fields such as Message Number, Time Initiated, Time Completed, and Time Message Completed. Such a grouping would have achieved a higher normal form classification for the database as a whole, but this organization was not necessary to achieve our desired objectives, and was therefore not adopted.

These queries are what the authors considered to be the basic useful (versus theoretical) relationships. Because of this, there is no implied data [Ref. 25: pp. 183 - 185]. Each separate message is a complete and distinct occurrence of the general structure discussed above. These queries are listed below, and can be broken down into two general categories. The first deals with the overall relationship of all messages within the database, and the queries associated with this functional relationship are listed below:

- Messages by type, or what is the number of messages according to message type, i.e., what is the number of fragmentary orders given, what is the number of spot reports sent, and so on?
- Messages by flow, or what number of messages flow either up, down, or across the tactical organization?
- Messages by type by flow, or what number of fragmentary orders flow up the chain of command, what number flow down, or across. Or, what number of spot reports do the same?
- Messages by activity, or how many messages were sent while the unit was in position, or in the attack, or just moving?
- Messages by type and activity, or how many of what type of report was sent while the unit was in position, or in the attack? That is to say, how many fragmentary orders were sent during the attacking phase, how many while moving, and so on?
- Messages by activity and flow, or how many messages flow up the chain of command while the unit was in position, or attacking, or merely moving? How many move down, or across?

The second major grouping of queries has to do with searching the database for the messages which exhibit the maximum characteristics for a given aspect of the voice-based communications, or for any particular attribute of interest to the analyst in the database. These queries include the following:

- What is the maximum number of characters in any message?
- What is the maximum number of seconds used in transmitting any message?
- What is the maximum number of characters per second transmitted in any message?
- What is the maximum number of seconds spent trying to establish contact with another unit on the battlefield?
- What is the maximum number of seconds between messages?
- What is the maximum number of characters of any message based upon the message flow, i.e., either up, down, or horizontally on the battlefield?
- What is the maximum number of seconds of any message based upon the message flow, i.e., either up, down, or horizontally on the battlefield?

- What is the maximum number of characters of any message based upon the activity of the unit?
- What is the maximum number of seconds of any message based upon the activity of the unit?
- What is the maximum number of characters of any message based upon the type of message sent?
- What is the maximum number of seconds of any message based upon the type of message sent?

It is these queries which will focus the authors' effort to determine the minimum acceptable requirement for BMS, and the derivation of those figures is what follows in Chapter Seven.

VII. DETERMINE THE VOICE REQUIREMENTS

A. INTRODUCTION

The application of BMS (i.e., computer-based technology) to the manner and method of our current reporting procedures would greatly simplify the process, provide a significant increase in the speed of reporting, and significantly improve the accuracy, timeliness, and integrity of information problems which are a direct result of 'the way we do business' today. Part of the process in applying existing technology has to do with defining the parameters of the information flow to support the passage of battlefield information within the execution of warfare as defined by the AirLand Battle doctrine. It is in this area of information flow architecture that this chapter will focus.

A major applications goal of this thesis it to demonstrate the utility of our approach to defining the data bit and data bit rate requirements and provide a framework within which others can work in order to correct the deficiencies provided by current systems. To assist these efforts, a database was developed. The files it contains are sequential files, representing the chronological flow of messages as they occurred by units in training at the NTC. As stated above, each of the database files can be accessed, joined, or otherwise manipulated in order to analyze a particular aspect of the radio traffic, and from the analysis determine the parameters on the requirements. The responses to the queries listed in Chapter Six will begin to quantify the information flow requirements prerequisite to the design of a system which will provide a quantum improvement over current communications systems.

This chapter will discuss the results of the database queries and their relationship to the voice requirements as exhibited by the current communications system. These results are the first step to determining the digital requirements necessary for a computerized system such as BMS that will be discussed in Chapter Eight. A research goal was to determine and analyze the peak stress on the current system as depicted by the voice requirements generated by two Battalion Task Forces at NTC, and to evaluate those limits against the capabilities of BMS in order to determine the impact that such a system may have on the modern battlefield. The authors maximized the results of the queries in order to develop their model upon which the baseline requirements for BMS would rest.

B. IDENTIFYING INFORMATION ARCHITECTURE

A message is essentially an exchange of transmissions which ends when one or both stations voluntarily stop the exchange of transmissions for reasons pertinent to the subject matter instead of technical difficulty. A complete message may consist of one transmission or many transmissions. For various reasons associated with the tactical situation or current capabilities of the communications systems these transmissions may be successful and contain battlefield information or be unsuccessful and contain garble, interference, or override. The Hasty Attack was selected for its ability to stress the existing communication system during a critical period on the battlefield. What follows is a brief discussion of the messages selected for the research effort.

A total of 1,194 messages were transcribed to the data worksheets. While this represented the initial sample. the authors further eliminated messages that were unreadable due to severe garble or interference. Therefore. the true sample size of messages were reduced to 479 observations across the seven frequencies. Table 3 lists the number of messages by frequency that were available and the number of messages by frequency that were actually used for our research.[23] The messages used for our sample size were observations taken from the 1194 messages transcribed from our tape recordings that met the requirements discussed in Chapter Five, Methodology. While these 479 messages represent 40% of the observations recorded during the Hasty Attack. they only represent approximately 25% of all possible messages actually transmitted during the Hasty Attack.

The message summaries shown in the following tables provide an illustration of the relationships between messages under different circumstances in relation to the dynamic battlefield required by the AirLand Battle doctrine. It should be noted that the totals may reflect what appear as discrepancies. This phenomenon is a result of the interpretation of data as it was transcribed from the recordings and the inability to determine an appropriate category for a specific element of the message. For example, a message may have been identified as a spot report, but no determination could be made as to what directional flow was intended. This could have occurred when one or

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[23] Total observations for all mission events conducted by the unit selected for the sample size were approximately 62% readable or partially readable. The other 38% were unreadable or identified by a light indicator as activity on the net. These last two occurrences were not transcribed on the data worksheets and therefore, are not a part of our sample size. The 1194 total messages represent readable or partially readable observations from approximately 62% of the readable or partially readable observations available on the NTC tapes. [Ref. 23].

TABLE 3

SAMPLE SIZE SUMMARY

	Total	Used	% Used
Frequency 1	111	59	53 %
Frequency 2	108	39	36 %
Frequency 3	65	11	17 %
Frequency 4	198	54	27 %
Frequency 5	384	184	48 %
Frequency 6	161	69	43 %
Frequency 7	167	63	38 %
TOTALS	1194	479	40%

more callsigns were missing. Therefore, this message was not read in the query which asked which spot report was the largest one sent based upon the flow of the information, since that information flow could not be identified. When information categories could be estimated based upon other information within the message, then the block in question was filled in and the message was considered a useful message for the purpose of our research. Otherwise, in answering several complicated questions, involving the joining of several attributes, a message may appear as the maximum requirement in one query but not in another. This apparent discrepancy had no adverse affect upon the authors outcomes, however, since the maximum requirements were captured one way or another, either by a simple or a complex query.

1. Type Report

The usable messages were categorized under four major types of orders. Refer to Table 4 for the types of messages and the number of occurrences of each type. These types of orders were more descriptive of the message contents and therefore, may actually include many report formats. For example, a spot report may be either a Commanders Situation Report, a Minefield Report, or a Flash Sitrep, and a fragmentary order may be a Hasty and Deliberate Attack Order, a Minefield

Operations Order, or a Delay Plan. The information provided in Table 4 indicates an almost even mix between fragmentary orders and spot reports. These two categories of reports represent 86% of all identifiable messages sent. Since the Hasty Attack involves, primarily, the movement to contact and attacking phases, this distribution appeared to support the validity of the authors' conclusion that the sample size is sufficiently large to accurately reflect reality and to use as a basis for determining minimum requirements for BMS. The category containing messages with 'No Content' was based upon messages that comprised failed attempts to establish contact or radio checks. These messages contained no useful information within the text of the message. While the eight percent represents the portion of our sample size that contained no content, it should be noted that the majority of the 60% observations not considered were filled with mostly garble, interference or override. These unreadable messages, by nature, may yield a higher than average percentage of transmissions designed to establish contact or make radio checks for the purpose of verifying radio maintenance. Therefore, the value of messages with no content is designed for comparison with the sample size (i.e., eight percent of sixty percent) and is not designed to establish a trend. For a more technical discussion of this category of messages see Reference 23, and for a point of view more concerned with the impact that human factors have on communications see Reference 24.

TABLE 4

SUMMARY OF REPORTS BY TYPE

Type Report	Totals	Percentages
Fragmentary Orders (FRAGOs)	167	44 %
Spot Reports	160	42 %
Contact Reports	50	13 %
Calls For Fire	4	1 %
No Content	33	8 %

2. Hierarchical Flow

Information on the battlefield which is generally status oriented basically moves from lower echelons to higher echelons, while the flow of information from higher to lower is generally command and control related, and horizontal flow (whether internal or external) is generally coordination oriented. These categories of information flow were simplified to represent the passing of useful information up, down, or across the organization. Table 5 shows that at least half of the messages transmitted during the Hasty Attack were processed from higher echelons to lower echelons. This trend seemed appropriate for the unplanned, spontaneous nature of the Hasty Attack. Over one third of the messages were sent from lower echelons to higher echelons.

TABLE 5
SUMMARY OF REPORTS BY HIERARCHICAL FLOW

Report Flow	Totals	Percentages
Flowing Up The Organization	136	36 %
Flowing Down The Organization	186	50 %
Flowing Across The Organization	53	14 %

3. Type Report by Hierarchical Flow

An essential element of battlefield information architecture involves the types of reports that are transmitted and the destination of each type of report. This knowledge leads, generally, into the issue of who talks to whom and what do they say. Tables 6, 7, and 8 summarize the frequency of each type of report in relation to the direction of information flow.

a. Reports Flowing Up the Organization

Table 6 provides the results of the number of messages by type of report that were directed up the tactical organization during the Hasty Attack. Almost three fourths of all messages transmitted from lower echelons to higher echelons were spot reports. This observation is consistent with the reality that subordinate elements, fighting the battle forward, are the 'eyes and ears' of the Battalion and are sending the most accurate information available up the chain of command for processing and use in decision making, supporting the conclusion that the sample size is sufficient to yield accurate conclusions.

TABLE 6

TYPE REPORT BY HIERARCHICAL FLOW (UP)

Type Report	Totals	Percentages
FRAGOs Flowing Up	12	10 %
Spot Reports Flowing Up	81	70 %
Contact Reports Flowing Up	22	19 %
Calls For Fire Flowing Up	1	1 %

b. Reports Flowing Down the Organization

The analysis of reports by type that were directed from higher echelons to lower echelons are summarized in Table 7. Almost 80% of all reports forwarded down the tactical organization represent command and control messages or fragmentary orders. Because the purpose behind a fragmentary order is to amend previous orders or issue new orders based upon changes in the tactical situation, it is appropriate for these orders to be directed from higher echelons to lower echelons. This once again validates conclusions reached from the sample size used in this analysis since this result confirms normal operational procedures in a Hasty Attack.

c. Reports Flowing Across the Organization

When determining the number of reports by type transmitted horizontally across the tactical organization, the authors were not concerned whether they were directed internally or externally, but whether they contained information or not and the category of that information. Refer to Table 8. Slightly more than half of the messages processed on the same level in the tactical hierarchy were spot reports. Because of the definition of a spot report as a rather large category of reports (see above discussion on Type Report), the spot reports could range from an element passing information to other units on the flanks to effecting necessary coordination for movement or the ensuing attack.

TABLE 7

TYPE REPORT BY HIERARCHICAL FLOW (DOWN)

Type Report	Totals	Percentages
FRAGOs Flowing Down	125	78 %
Spot Reports Flowing Down	21	13 %
Contact Reports Flowing Down	13	8 %
Calls For Fire Flowing Down	2	1 %

TABLE 8

TYPE REPORT BY HIERARCHICAL FLOW (ACROSS)

Type Report	Totals	Percentages
FRAGOs Flowing Across	13	35 %
Spot Reports Flowing Across	20	54 %
Contact Reports Flowing Across	4	11 %
Calls For Fire Flowing Across	0	0 %

4. Activity

By quantifying the number of messages sent during different activity phases of the Hasty Attack, a trend for when the maximum utilization of the net may be established. The authors identified four major activity phases for the Hasty Attack. See Table 9 for the results. The four categories were determined based on the phase that the task force was proceeding through. No attempt was made to capture the activity of individual elements within the task force. Given this structure, an almost equal amount of messages were sent while either moving or in the attack; together they comprised 92% of all messages sent. While this may be an obvious occurrence, since both events constitute rapid changes in the tactical situation, the results give credence, once again, to the contents of the database.

TABLE 9

SUMMARY OF TYPE REPORT SENT BY ACTIVITY

Activity	Totals	Percentages
Sent While In Position	19	4 %
Sent While Moving	212	45 %
Sent While Attacking	218	47 %
Sent While In Contact	20	4 %

5. Type Report by Activity

After the breakdown of messages by activity was determined, the authors determined the type of report that was transmitted during each phase. This query provided direction for what is said and when it is said. The analysis is summarized below in Tables 10, 11, and 12.

a. Type Report Sent While in Position

See Table 10 for a list of the number of messages sent by type of report while in position. It was not unusual for this phase to yield one of the lowest occurrences of observations, since units conducting a Hasty Attack are rarely 'in position'. However, an obvious trend was still evident. While in position, 70% of all messages were categorized as spot reports. This may be as a result of a message being sent at the short halt after the completion of a significant activity on the battlefield (like engaging an enemy target, or breeching a minefield). If so, this phenomenon is indicative that the effort to both fight and report at the same time is not possible, and it is this cognitive overload that BMS is designed to reduce, permitting better fighting and better reporting. The low incidence of fragmentary orders and contact reports sent while in position could be a result of the nature of the Hasty Attack, but this does not invalidate the conclusion regarding spot reports developed above.

b. Type Report Sent While Moving

Once the unit began the movement phase, the battle became more dynamic. The rapidly changing tactical situation provided a greater occurrence of transmissions. Table 11 illustrates the results. As noted, more than half of all messages sent were command and control oriented. Over one third of all messages were categorized as spot reports.

TABLE 10

TYPE REPORT SENT WHILE IN POSITION

Type Report	Totals	Percentages
FRAGOs Sent While In Position	3	18 %
Spot Reports Sent While In Position	12	70 %
Contact Reports Sent While In Position	2	12 %
Calls For Fire Sent While In Position	0	0 %

TABLE 11

TYPE REPORT SENT WHILE MOVING

Type Report	Totals	Percentages
FRAGOs Sent While Moving	91	53 %
Spot Reports Sent While Moving	59	35 %
Contact Reports Sent While Moving	21	12 %
Calls For Fire Sent While Moving	0	0 %

c. *Type Report Sent While Attacking*

Table 12 contains the number of messages by type report sent while in the Hasty Attack mode. This phase represents an unplanned, spontaneous action on the battlefield that conceivably stresses the communications systems. The requirements for sending messages in all directional flows exists. Notably, the units in contact would be feeding back intelligence-oriented messages or spot reports to higher echelons that would solicit a fragmentary order in return. This represents a completed decision cycle. This conclusion is validated by experience as well. An even proportion of fragmentary orders, 70%, and spot reports, 71%, were processed during this phase.

TABLE 12

TYPE REPORT SENT WHILE ATTACKING

Type Report	Totals	Percentages
FRAGOs Sent While Attacking	70	42 %
Spot Reports Sent While Attacking	71	43 %
Contact Reports Sent While Attacking	24	14 %
Calls For Fire Sent While Attacking	2	1 %

d. *Type Report Sent While In Contact*

This category is characterized by an element or unit receiving hostile fire or coming under the influence of the enemy by the enemy while not decisively engaged during the attacking phase. Refer to Table 13 for the number of occurrences of each report while in contact. An overwhelming number of messages were spot reports, which reflects the lower to higher transmission of information pertaining to degree of contact and the status of the unit in contact.[24]

TABLE 13

TYPE REPORT SENT WHILE IN POSITION

Type Report	Totals	Percentages
FRAGOs Sent While In Contact	3	15 %
Spot Reports Sent While In Contact	14	70 %
Contact Reports Sent While In Contact	2	10 %
Calls For Fire Sent While In Contact	1	5 %

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[24] The large discrepancy between spot reports and fragmentary orders may be effected by the administrative involvement in the exercise by the controllers. Several elements may have initiated contact reports to indicate that they have been temporarily "killed" by controller action.

6. Hierarchical Flow by Activity

This last group of categories provided another approach to the question of who talked to whom, and when. While this group is general in nature, it provides an answer as to which phase of a Hasty Attack stresses the communications systems the most. Tables 14, 15, and 16 list the number of occurrences of each category. A brief discussion of each table will follow.

a. Flow of Messages Sent While In Position

Table 14 presents the number of occurrences where messages were directed up, down, and across the tactical organization from elements that were in position. While this sample size is very small, 17 messages, it provides a realistic representation of the percentage expected. Almost half of the messages flowed up from lower echelons to higher echelons. This implies that while units were in position and the battle was more static, they provided intelligence-oriented information and status reports as necessary.

TABLE 14

MESSAGE FLOW WHILE IN POSITION

Message Flow	Totals	Percentage
Flowing Up While In Position	8	47 %
Flowing Down While In Position	5	29 %
Flowing Across While In Position	4	24 %

b. Flow of Messages Sent While Moving

This category provided the largest number of observations within the group. The relationship between stress on the communications systems and the dynamics of the battlefield has already been established. Table 15 shows that more than 60% of all transmissions during this phase were sent from higher echelons to lower echelons. This indicates that a relationship between the dynamics of the battlefield and the direction of message flow exists where messages become more command and control oriented as the battle becomes less predictable. Since this is a reasonable assumption. here is another verification of the sample size and its contents used during the research.

TABLE 15
MESSAGE FLOW WHILE MOVING

Message Flow	Totals	Percentages
Flowing Up While Moving	46	27 %
Flowing Down While Moving	107	63 %
Flowing Across While Moving	16	10 %

c. *Flow of Messages Sent While Attacking*

Table 16 illustrates the results of the number of occurrences of message flow throughout the tactical organization while the unit was attacking. As shown, an almost equal number of messages were sent from lower to higher as there were from higher to lower. The conclusion is that higher echelons responded to the information they received pertaining to the battle and responded with directives to their subordinates.

TABLE 16
MESSAGE FLOW WHILE ATTACKING

Message Flow	Totals	Percentages
Flowing Up While Attacking	68	40 %
Flowing Down While Attacking	71	41 %
Flowing Across While Attacking	32	19 %

d. *Flow of Messages Sent While In Contact*

While this last category provided a small number of occurrences (there are only a total of 17 messages), 65% of the messages recorded flowed up while the unit was in contact, indicating that elements that were under enemy fire were providing information to higher echelons.[25] See Table 17 for a complete listing of the data. This is another reflection of the relationship between the dynamics of the battlefield and the validity of the results capable of being drawn from the authors database.

TABLE 17

MESSAGE FLOW WHILE IN CONTACT

Message Flow	Totals	Percentages
Flowing Up While In Contact	11	65 %
Flowing Down While In Contact	5	29 %
Flowing Across While In Contact	1	6 %

C. MAXIMIZING INFORMATION REQUIREMENTS

A research goal was to determine the parameters of the points of maximum system utilization, and to evaluate those limits against a computerized system such as BMS in order to determine the impact that such a new system may have on the modern battlefield. Prior to any attempt to determine the digital requirements of a system, it was necessary to establish a profile of the voice requirements for the selected sample. By establishing a well-defined profile of the voice communications requirements, future attempts to digitize communications will be enhanced. Appendix C lists, in a summarized fashion, the data averages and maximums for all seven frequencies. The following discussion provides a summary of the results of the findings.

1. Characters Per Second

Defining the characteristics of any communications architecture requires modelling the sample in terms of characters and seconds. Table 18 provides the averages and maximums of the sample size in these terms. Additional tables consider various situations influenced by the dynamics of the battlefield and will be discussed in more detail later. The averages are for comparison only. The authors did not eliminate any maximums based on extraordinary variances between the maximums and the averages. Table 18 shows that over seven frequencies the maximum number of characters encountered in any message was 1,381 whereas the average was only 167. The maximum number of seconds in a message was 328 whereas the average was only 33.

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[25] The discrepancy between the flow of transmissions up versus the flow of transmissions down the tactical organization may be influenced by the administrative situations provided by the controllers of the exercise. The numbers may reflect occurrences where subordinate elements near the battle were "killed" and reported the incident to their higher headquarters and thus no response or directive was required.

The next step was to determine the maximum number of characters per second in any message. This process involved computing the characters per second for each message in the sample and identifying the maximum, which was 27. As noted from the table these maximums do represent extremes from the averages. The indication is that an optimum stress level was achieved.

TABLE 18

AVERAGE AND MAXIMUM CHARACTERS, SECONDS

Category	Average	Maximum
Characters In A Message	167	1381
Seconds In A Message	33	328
Characters Per Second	7	27

2. Establish Contact and Wait Between Messages

Table 19 provides the information obtained when each message was analyzed for the time, in seconds, required to establish contact and the number of seconds between each attempt to make contact. The duration of time required to establish contact by the calling callsign was computed from the first attempt and concluded when the calling callsign discontinued attempts to contact or received acknowledgement by the called callsign. The timing was conducted for every message in the sample and the maximum across seven frequencies was selected. The maximum value of 159 seconds again represents a wide disparity from the average of 16 seconds.

The maximum number of seconds between messages is also shown in Table 19. The amount of time expired between each message was computed and the maximum value was extracted from all seven frequencies. The time interval was based on the difference between the stop time of a message and the start time of the next message. The maximum separation between messages was 3,055 seconds compared to the average of 185 seconds. The large variance may be partially explained by the unit's particular mission on that net. For example, the scouts may have fewer transmissions as the battle progresses into the attacking phase.

TABLE 19

AVERAGE AND MAXIMUM SECONDS, MESSAGES

Category	Average	Maximum
Seconds Required To Establish Contact	16	159
Seconds Between Messages	185	3,055

3. Hierarchical Flow

The maximums for each message within a frequency based on hierarchical flow provided insight to the demands on the system in terms of who transmitted the longest messages. As shown in Table 20, the maximum number of characters produced in a message across all seven frequencies was produced by a message that was transmitted from lower to higher.

TABLE 20

AVERAGE AND MAXIMUM CHAR/MSG BY FLOW

Category	Average	Maximum
Flowing Up	203	1,022
Flowing Down	108	728
Flowing Across	129	594

The maximum number of seconds of any message based on hierarchical flow was determined for the same reasons as the maximum number of characters. Table 21 show the results in terms of time, in seconds. Again, the maximum number of seconds for any message was found in a message that was sent from a subordinate element to a higher element.

TABLE 21

AVERAGE AND MAXIMUM SEC/MSG BY FLOW

Category	Average	Maximum
Flowing Up	48	328
Flowing Down	15	143
Flowing Across	13	126

4. Activity

The activity phase provided input to the various levels of stress obtained from the phases of the battle and the impact on message lengths. Table 22 shows the maximum number of characters of any message during all phases of the Hasty Attack. The maximum characters were transmitted by an element while in position, 1,381 characters. This was closely followed by a message that was sent while moving, 1,022 characters.

TABLE 22

AVERAGE AND MAXIMUM CHAR/MSG BY ACTIVITY

Category	Average	Maximum
While In Position	506	1,381
While Moving	118	1,022
While Attacking	111	847
While In Contact	120	716

Table 23 shows the same analogy applied to maximum number of seconds for any message during each of the phases. The results parallel those found in Table 22. The longest message in terms of seconds was sent while in position followed by a message transmitted while moving.

TABLE 23
AVERAGE AND MAXIMUM SEC/MSG BY ACTIVITY

Category	Average	Maximum
While In Position	102	267
While Moving	20	186
While Attacking	17	143
While In Contact	34	272

5. Type of Report

The maximum characters of any message by type of report revealed the relative length of each type of report. By virtue of our sample shown in Table 24, the contact report yielded the longest message transmitted, 1,381 characters. This may be effected by whether the message was formatted or unformatted. In our case the message was unformatted and, in determining maximum stress on the voice requirements, had no bearing on our acceptance of the results.

The last table provides the maximum number of seconds of any message based on type of report. While the trend in the past has been for the maximum number of seconds to occur in the same category as the maximum number of characters, Table 25 shows that an unformatted spot report, from across the seven frequencies, contained the maximum number of seconds. There is no unusual explanation for this other than it has no significant bearing on our efforts to achieve maximum stress of the communications systems.

D. SUMMARY

The authors summarized the maximums across the sample size in order to quantify the greatest information flow requirement (i.e., the most stress) as depicted by

TABLE 24

AVERAGE AND MAXIMUM CHAR/MSG BY REPORT

Type Report	Average	Maximum
Fragmentary Order	103	645
Spot Report	171	792
Contact Report	348	1381
Call For Fire	193	343

TABLE 25

AVERAGE AND MAXIMUM SECS/MSG BY REPORT

Type Report	Average	Maximum
Fragmentary Order	14	143
Spot Report	40	328
Contact Report	60	267
Call For Fire	51	96

the voice-based model. In addition, they established that both the quantity and quality of of the radio communications recordings were sufficient for the authors' research. The results indicated that the communications model was within expectations for the mission selected and while the sample size was limited, it represented values that could be used to derive the digital requirements to be discussed in Chapter Eight. The authors did not attempt to explain the circumstances for each observance from a humanistic point of view. The instances where the maximums varied by extremes from the average were not included as part of the focus of the thesis, but were considered useful for achieving the optimum stress on the communications systems. There were some irregularities in the totals presented under the message summaries that were created as part of the subjective selection process discussed in Chapter Five and expanded in this chapter. However, these discrepancies posed no significant problems for using the NTC tapes and the selected sample size for modeling the communications architecture for application in this or future research efforts.

To conclude this chapter, a quick summary of the major conclusions concerning the structure of the information architecture of the Hasty Attack include the following observations:

- The greatest number of messages sent were fragmentary orders
- More messages flowed down
- Of the messages flowing up, the majority were spot reports
- Of the messages flowing down, the majority were fragmentary orders
- Of the messages flowing across, the majority were spot reports
- In the Hasty Attack more messages were sent while attacking
- While in position, the majority of the messages were spot reports
- While moving, the majority of the messages were fragmentary orders
- While attacking, there was an almost equal number of fragmentary orders as there were spot reports
- While in contact, the majority of the messages were spot reports
- While in position, the majority of the messages flowed up
- While moving, the majority of the messages flowed down
- While attacking an equal number of messages flowed both up and down
- While in contact, the majority of messages flowed up

VIII. DETERMINE THE DIGITAL REQUIREMENTS

A. INTRODUCTION

The quantification of the voice-based requirements is hoped to provide a frame of reference to permit comparison of the current system to BMS and to suggest a meaningful lower bound on some architectural decisions for BMS. While the focus of this thesis is not architectural (i.e., technical) in nature, the authors recognize the relationship between a logical and a physical system. and the impact each has on the other. Therefore, examples will be provided below which demonstrate the benefit of having a system capable of doing what BMS is envisioned being able to do, but these examples are only precise enough to quantify the basic principle being discussed, and should not to be used in a more rigorous, more demanding context.

B. THE DIGITAL REQUIREMENTS

1. The Data Bit Requirement (Actual)

In order to determine the digital requirements as established by the data available, several conventions have to be assumed in order to be able to translate the voice- and character-based analysis of the previous chapter into computer- and digital-based parameters in this chapter. The decisions regarding these conventions will be made independent of any hardware-specific requirements, and will be kept as general and as functional as possible in order to illustrate the basic principles without bias. One necessary, fundamental decision will be assumed here; others will be stated as they are appropriate. This first one has to do with the choice of which character-to-bit translation scheme to use. Since one purpose of this thesis is to quantify the memory (random access memory, RAM) size necessary to support a company in the Hasty Attack, a general scheme of eight bits per character will be used.[26]

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[26] To provide a perspective, however, in the work at Fort Lewis, WA, under the combined efforts of the Project Manager, Operations Tactical Data Systems (PM-OPTADS), the Communications Electronics Command (CECOM), the Army Development and Employment Agency (ADEA) and the 9ID (MTZ), titled Maneuver Control System 2 (MCS2), an ASCII scheme, a parity bit, and a stop/start bit is used in their character-to-bit translation. The point is that many different choices are possible, and that the specific details will vary depending upon the ultimate choice of the protocol to be used. The intent of the thesis is not to explore these alternatives, nor to argue for one as opposed to the other.

The data bit requirements (memory size) necessary to support company-level tactical operations will be defined by the sizes of the reports used most frequently during the Hasty Attack. The conversion of the maximum voice requirements as determined in Chapter Seven above will set the lower bound on an acceptable memory size for BMS.[27]

The four reports used most frequently during the conduct of this mission were the Fragmentary Order (FRAGO), the Spot Report, the Contact Report, and the Call For Fire. The maximum number of characters needed to send these reports is provided below in Table 26. Translating the maximum requirement into bits (i.e., multiplying 1,381 by eight) generates a minimum requirement for the Hasty Attack for BMS at 11,048 bits. Said another way, approximately 10.79 Kbits of RAM is necessary to support the information exchange portion of a company in the Hasty Attack.

TABLE 26

MAXIMUM NUMBER OF CHARACTERS BY TYPE REPORT

Type Report	Char	Bits
Fragmentary Order	645	5,160
Spot Report	792	6,336
Contact Report	1,381	11,048
Call For Fire	343	2,744
MAXIMUM	1,381	11,048

2. The Data Bit Requirement (Doctrinal)

The two documents used to provide the data for the doctrinal information requirement at the company level are References 26 and 27. Each doctrinal report was classified as to whether or not it fell into one of the authors' four message categories, and if it did, which one. From this analysis, the largest type of each report was compared with the empirically derived data. Table 27, below, shows the comparison between the two message sizes by type of report, one actual and the other doctrinal.

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[27] A point of clarification may be necessary here. Only the random access memory (RAM) size requirements necessary to support the Hasty Attack are being defined here. This excludes the amount of read only memory (ROM) necessary for the operating system, including all of the input output, memory management, and other related functions, and any amount for imbedded report formats. All these represent additional requirements over and above what is being derived.

TABLE 27

ACTUAL VS. DOCTRINAL MESSAGE SIZES

(Size Given In Number Of Characters Required)

Report Type	Actual	Doctrinal	Largest
FRAGO	645	1200	Doctrinal
Spot	792	500	Actual
Contact	1381	200	Actual
Call Fire	343	200	Actual
MAXIMUM	1381	1200	Actual

This comparison indicates that at the company level the demonstration of the requirements as indicated by the units whose performance established the authors' sample exceeds the requirements as established doctrinally, and is the better of the two upon which to begin to define requirements for BMS.

3. The Data Bit Rate Requirement

A second purpose of this thesis was to quantify the information exchange rate (i.e., bit transfer rate) necessary to do this. The requirement will be determined by the highest character-per-second transfer-rate as exhibited by either of the two Battalion Task Forces at NTC. This figure equates to the maximum amount of information the current system demonstrated it needed to pass, per second, in order to support a company in the Hasty Attack. See Table 28, below, for the maximum characters per second requirement throughout each of the seven frequencies in the database. As is seen, the maximum character per second rate found in the data available is twenty-seven characters (or 216 bits) per second.[28]

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[28] The issues of message protocols relating to the presence of parity bits, stop/start bits, synchronous or asynchronous message transfer, the amount and type of header and trailer data required, and problems associated with synchronization (among others) will be conveniently set aside since they are outside the focus of this thesis.

TABLE 28

THE MAXIMUM TRANSFER RATES

Frequency	Characters Per Second
1	27
2	22
3	8
4	16
5	20
6	22
7	20
MAXIMUM	27

C. TRADE-OFF ANALYSIS

1. Choosing a Microprocessor

The purpose of this portion of the thesis will be to examine the capabilities of several processors (micro, and otherwise) already in use in the Department of Defense to determine their relative merit regarding their usefulness in supporting the communication requirements of AirLand Battle. The parameters of average instruction execution time and average (theoretical) throughput of each processor have been assumed as the parameters driving the comparison.

2. Information Requirements

Three general information mixes (the Gibson mix, the Real-Time mix, and the Message Processing mix) have been chosen to evaluate the relative performance of the processors identified below.[29] These mixes are industry-standard tools by which a given microprocessor's performance can be evaluated relative to a known measure. Each of the mixes reflect a different processing requirement in relation to the number of mathematical operations anticipated, the number of transfers of data between the components of the computer, and the like [Ref. 28: p. 19]. It is postulated that even though the exact nature of the information requirements of a battalion (or company) in combat is not yet defined, that by examining the relative performance of processors in defined, controlled circumstances that the scope of choices for potential microprocessors to be used to meet the needs of BMS will at least be reduced, and at best, the choice itself will be possible. See Table 29 for a complete listing of the relative number (the percentage) of instructions per mix.

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[29] For further study of the technique used here, see Jack Corsiglia, " Matching Computers to the Job-First Step Towards Selection," *Data Processing Magazine*, December 1970, and Louis Wolin, "Procedure Evaluates Computers For Scientific Applications," *Computer Design*, November 1976.

TABLE 29
INFORMATION PROCESSING MIXES

(In Percentages)

Type of Instruction	Gibson	Real Time	Msg. Proc.
Add/Subtract	6.1	16.0	5.0
Multiply	0.6	5.0	0.5
Divide	0.2	2.0	0.5
Compare	3.8	12.0	1.0
Shift	4.4	5.0	3.0
And/Or	1.6	4.0	15.0
Load/Store	31.2	33.0	47.0
Conditional Transfer	16.6	10.0	14.0
Increment Memory	18.0	4.0	3.0
Reg to Reg Move of Data	5.3	5.0	8.0
Programmed I/O Transfer	0.0	2.0	5.0
Initialize Buffered I/O	0.0	1.0	0.1
Interrupt Response	12.2	1.0	0.1

3. Militarized Processors Available

The three processors currently in use chosen for this study are Univac's AN/UYK-7 (a 32-bit processor) and AN/UYK-20 (a 16-bit processor), and the MILSPEC version of the Intel 8086, known as the 80C86 (also a 16-bit processor), with an 8 MHz clock.[30] See Table 30 for a complete description of the timing figures utilized for comparative purposes. These figures are the 'worst case' timing figures, and are given in number of microseconds per execution per type of instruction [Ref. 29]. The AN/UYK-7 and the AN/UYK-20 were chosen for this analysis because they are in use in PLRS, which is the closest functional equivalent to a BMS-like activity on the battlefield. The 80C86 is chosen because it is the authors' opinion that it is the 'workhorse' among the microprocessors, and deserves serious consideration for utilization.

TABLE 30

MICROPROCESSOR EXECUTION SPEED

(Microseconds Per Instruction Execution)

Type of Instruction	80C86	AN/UYK-20	AN/UYK-7
Add/Subtract	2.60	2.25	1.50
Multiply	19.50	4.60	7.75
Divide	23.60	7.50	15.00
Compare	2.60	2.25	1.50
Shift	4.00	3.20	1.75
And/Or	2.60	2.25	1.50
Load/Store	2.60	2.25	1.50
Conditional Transfer	1.00	2.40	1.50
Increment Memory	2.50	2.40	2.50
Reg to Reg Move of Data	0.25	0.75	1.50
Programmed I/O Transfer	1.25	3.00	3.50
Initialize Buffered I/O	1.25	4.50	3.50
Interrupt Response	11.00	10.50	10.00

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[30] It should be recognized that the MIL-STD-1553B databus is an eight-bit bus, and that the use of more capable processors implies the use of some additional hardware to interface the two. Upgrading this databus to a thirty-two bit bus to support its central position of importance in terms of relaying data internally for BMS might be a worthwhile vehicle upgrade to consider in the future.

4. Comparative Analysis

The analysis will compare the average instruction execution time of each processor, their theoretical throughput, and, finally, their cost/performance ratio.

a. Average Mix Execution Time

In order to determine the average execution time for each processor for each mix of data above, the columns in the two different tables are multiplied by each other and the individual products are then summed. This will produce a weighted average for the execution time for each processor. The data given below in Table 31 is in microseconds.

TABLE 31
WEIGHTED AVERAGE MIX EXECUTION TIME

(In Microseconds Per Mix)

Microprocessor	Gibson	Real Time	Msg. Proc.
80C86	3.42165	3.697	2.40775
AN/UYK-20	3.2953	2.586	2.303
AN/UYK-7	2.7925	2.28	1.74675
FASTEST	AN/UYK-7	AN/UYK-7	AN/UYK-7

b. Theoretical Throughput

Another measure of relative computer performance besides average execution time per instruction mix is theoretical throughput, or, the number of instructions executed in a given period of time. Throughput can be calculated as the inverse of the average mix execution time, and is provided below in Table 32 for each of the processors and mixes under analysis. Results are given in the number of instructions completed per microsecond.

c. Cost/Performance Ratio

In both measures of performance, (i.e., estimated instruction mix execution time and theoretical throughput) the AN/UYK-7 demonstrated the greatest performance capabilities. However, when comparing its price with its relative performance, the AN/UYK-7 does not appear to justify itself (mission concerns, other necessary features or other requirements notwithstanding). The approximate cost data (in thousands of dollars) for each microprocessor is provided below in Table 33.

TABLE 32

THEORETICAL THROUGHPUT

(Instructions Per Microsecond)

Microprocessor	Gibson	Real Time	Msg. Proc.
80C86	2.92575	3.03463	3.58103
AN/UYK-20	2.7049	3.86698	4.38597
AN/UYK-7	4.15326	4.34216	5.72492
MOST PRODUCTIVE	AN/UYK-7	AN/UYK-7	AN/UYK-7

TABLE 33

APPROXIMATE COST FIGURES

(In 'K' Dollars)

Processor	Cost
80C86	1
AN/UYK-20	80
AN/UYK-7	500

When comparing cost with execution time, the price increase required to improve performance does not appear justified. In order to realize the minimum improvement, a 3.69% increase in speed (i.e., time saved) by moving from the 80C86 to the AN/UYK-20 in the Gibson mix, an 8,000% (i.e., 80 fold) increase in cost is required. Additionally, in order to realize the maximum possible improvement, a 38.33% increase in speed by moving from the 80C86 to the AN/UYK-7 in the Real Time mix, a 50,000% (i.e., 500 fold) increase in cost is required. The price does not appear to be warranted, all else being equal.

When comparing cost with theoretical throughput, the price increase does also not appear to be justified. In fact, moving 'up' in cost from the 80C86 to the AN/UYK-20 produces a decrease in theoretical throughput by 7.45% in the Gibson mix. However, in order to realize any increase in performance at all, the 80C86 must be swapped for the AN/UYK-7, and in the Message Processing mix this produces a 160% increase in performance, but at an incommensurable high cost. (a 50,000% increase). Once again, the costs alone do not appear to justify the use of the newer, faster processors. It is possible to link up to four 80C86 microprocessors in a multitasking mode, dedicate them to performing related but independent subfunctions of the overall task, and achieve the same time benefits present with the AN/UYK-7, but without the high cost nor the weight and size problems associated with the AN/UYK-7's or -20's.

D. SUMMARY

1. Implication of Data Bit and Data Bit Rate Required

In terms of digitizing the communications system in general, one obvious conclusion that can be reached is that the requirements to support the information normally relayed by voice do not approach the upper limits of the capabilities of the existing system if the voice itself is just digitized and relayed at 219 bits per second on it. This portion of the overall requirement to conduct a Hasty Attack did not stress the system. A second conclusion that can be reached is that no unreasonable hardware requirements are demanded. As demonstrated above, only 11K of memory is required to support the transfer of information now relayed by voice. These two conclusions support a larger conclusion that the design criteria for BMS should NOT be focused or driven by the information (textual or verbal) requirements, but perhaps by other requirements to support a Hasty Attack, such as the requirement to send graphical data.

This larger conclusion is further supported by the observation that the total amount of time spent communicating by voice on these seven frequencies can be summed to a total of 12,773 seconds of radio air time in order to relay 81,446 characters of information. This is approximately equal to 213 minutes, or 3.55 hours, of total air time. This air time represents approximately 22 hours of tape recording time, i.e., 22 hours of different units conducting a Hasty Attack. Even with a rather unsophisticated processor capable of operating at the maximum requirements demonstrated by the voice-driven system (i.e., 216 bits per second), the amount of total time spent on the air is reduced to 3,016.52 seconds, approximately equal to 50 minutes. This rather simple approach represents a 76.38% reduction in the amount of radio time. If a somewhat more sophisticated processor, capable of operating at the maximum capacity of our current system (1,200 bits per second) is employed, the total amount of time can be reduced to 542.97 seconds, which represents a 95.75% reduction in the electromagnetic signature of a Battalion. The Battalion almost disappears from the electromagnetic spectrum on the battlefield. This reduction of radio air time provides a significant reduction in the amount of stress placed upon the system, and permits serious consideration of protocols which support multiple users, like time division multiplexing, logical multiplexing, or statistical multiplexing. Table 34, below, provides a summary of the figures discussed above, and summarizes the benefits to be obtained (in terms of reducing the electromagnetic signature of a maneuver battalion through the use of a digital communications device operating at its maximum capacity) once BMS is fielded. These benefits are shown for its initial fielding using existing radios, and with the SINCGARS family of radios.

TABLE 34

REDUCTION OF AIR-TIME BENEFITS COMPARED

System Capabilities	# Bits	# Minutes	% Reduction
Current System	651,568	213	None
216 bps	Same	50	76.4%
1,200 bps	Same	9	95.8%
16,000 bps	Same	0.7	99.7%

2. Implication of Cost/Performance Analysis

Looking briefly at the performance analysis and cost/benefit ratios detailed above, it should be obvious that a new processor, capable of extremely quick calculations, may not be cost-justified on the basis of the information flow described herein. On a performance basis alone, the AN/UYK-7 outperformed the other two processors in all categories, but its margin of performance was not large enough to overcome its cost. In a cost-oriented evaluation, the 80C86 provided more performance for the dollar, and it is this ratio which might persuade decision-makers to opt for the 80C86 over newer processors which are only marginally more capable but extremely more expensive. If the 80C86 is configured in a distributed fashion so that each microprocessor performs a unique function, then the combination of up to five or six of these processors to achieve the same throughput and execution speed of one of the AN/UYK-7's or -20's, but without the cost prohibitions, might be the best solution yet. Another factor supporting this decision is the low weight of an 80C86, which would make such a configuration also possible. Such a load sharing, multimicro configuration would also provide for increased reliability of the overall system. This redundancy is a prerequisite to any military application.

In conclusion, however, this is not to say that no benefits could be obtained from implementing a digital information exchanging device into each combat vehicle, as will be shown in the following chapter. The authors selected what could be considered 'worst case scenarios' in order to highlight the positive impact BMS is capable of having on the battlefield. In these scenarios, the maximum number of bits per second of our current system (1,200) will be used to demonstrate the advantage which BMS will have since it was assumed earlier (in Chapter Four, above) that BMS will be fielded with our existing radios. Once SINCGARS is fielded however, with its increased bits per second and frequency hopping capability, benefits in terms of throughput and security will be significantly greater than the benefits modelled herein, and the disadvantages (like average delay, or message queue size) can be expected to decrease dramatically.

IX. TACTICAL APPLICATIONS AND VALIDATION OF REQUIREMENTS

A. INTRODUCTION

One of the most critical payoffs on the dynamic battlefield is survivability. The need for survivability will drive the momentum for major changes in the way command and control is executed. Survivable command and control capabilities are essential before a conflict, during the first stages of the conflict, and throughout the conflict. Command and control must be able to collect and provide the information needed to decide courses of action. In addition, it must be able to carry the decisions to unit commanders in the field. On the modern battlefield, with advanced weaponry and greater numbers of weapons, the advantage of timely and accurate intelligence can provide an advantage not defined in numbers. However, deficiencies in command and control organization and practices are brought to light by field exercises.[31] Two examples were extracted from our sampled units' Hasty Attack that reflected catastrophic events that impeded the units' ability to continue the mission. The emphasis was on the decision-making processes involved in these two examples. To provide some evidence of the interactive effect of automation and communications, the authors applied digital factors derived in Chapter Eight to the voice transmissions of the events. The results can be seen, by comparing actual performance of the unit in (simulated) combat to what may have happened had they had a system such as BMS to use in the same circumstances. Both examples were quite extensive, transmitting, in one instance, a contact report, a call for fire, and a spot report; in the other, a spot report, a series of fragmentary orders, and a contact report. In these two examples, all the basic types of reports were covered.

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[31] These ideas were taken from several articles that appear in Field Circular 101-34, *Command and Control on the AirLand Battlefield*, Selected Readings, U. S. Army Command and General Staff College, Ft. Leavenworth, Kansas, June, 1984. The articles in this circular provide different perspectives on several command, control, and communications issues.

B. ANALYSIS OF EFFECT

1. Example One--Scout's Movement to Contact

a. What Happened

The Scout Platoon was given a mission in support of the Task Force. They crossed the Line of Departure and conducted the Movement to Contact. One of the elements identified dismounted infantry and BMPs on top of a hill. The messages summarized below provide an overview of the events that transpired immediately following the initial report. In the message number, the first number represents the frequency and the second number represents the actual message number, for example, 1/033 means Frequency (1), Message (033). Message numbers containing ***** implies the message exists within our initial sample, but not retained in our database. These messages contain enough of the text to determine the purpose of the message. The message number was for reference to obtain the message's characteristics as defined in Appendix B.

- Message 1/033 -- Initially reported being engaged by enemy observed on top of a hill; requested guidance
- Message 1/034 -- Frago to get out of the area
- Message 1/035 -- Element in contact requested indirect artillery fire
- Message 1/036 -- Conducted withdrawal
- Message 1/037 -- Engaged enemy with direct fire weapon system
- Message 1/049 -- Scout Platoon Leader becomes a casualty
- Message 1/050 -- Scout Platoon Sergeant assumes control; requests status
- Message 1/051 -- Scout Platoon Sergeant came under fire; forwarded spot report to higher headquarters; asks for coordinates where engagement took place
- Message ***** -- Subordinate element attempts to send spot report to Scout Platoon Sergeant
- Message 1/052 -- Higher headquarters acknowledges spot report of enemy location, type, and number

b. The Results

The ensuing confusion, marked by a transition of control, stressed the communications system resulting in an increased number of transmissions with garble, interference and override. It was at this point, that the Scouts' forward progress was halted and the unit became decisively engaged. They never recovered and subsequently, were unable to bypass the enemy. The Scout Platoon Leader was among the battle losses.

c. *The Issues*

The list below summarizes the major evaluation areas drawn from this example:

1. There was no message forwarding the Artillery Request to the appropriate artillery unit. In addition, no messages acknowledging the Artillery Report was received or processed (i.e., no report of rounds impacting in the target area).[32]
2. The total time elapsed on the battlefield from the time one of the Scout elements reported he was initially engaged by the enemy, thought about indirect artillery, requested indirect artillery, and then engaged the enemy with direct fire, was 289 seconds (a little under five minutes).
3. Higher headquarters received a good spot report 24.3 minutes later, at Message 1 052, that required in almost 2 minutes of air time to transmit.
4. Scouts were unable to proceed beyond the enemy's initial screen.
5. The Scout Platoon Leader was killed 11 minutes after the initial report of receiving enemy fires. Message 1/033.

d. *With BMS*

The following discussion provides a hypothetical analysis of the above example using BMS. One assumption was that the unit was configured with existing radios, transmitting at a maximum rate of 1,200 bits per second. The other assumption was that the decision time will remain a constant.

1. Scout element was engaged by enemy. Scout element lased to the enemy. With the laser, the element is able to determine the enemy location, then send a contact report. This could be accomplish in less than .05 seconds as compared with the 12 seconds required initially.
2. User then punches Spot Report on the digital display screen, then enters enemy description and action taken. Note that the time is a function of the system and enemy location is known based upon your location which is continuously updated by the system. The same message as above, processed with BMS, would take .66 seconds to transmit. The Platoon Leader now has the information available to begin his analysis of the activity.
3. Almost simultaneously, the Task Force S-2 knows where the enemy is from the information he received on his display.
4. Had BMS with message verification been on hand, the call for fire would have taken less time, saving 20.9 seconds of transmission time and acknowledgement would have been received. While this may seem insignificant, it is important to note that most of the time that expired during this period was consumed by the decision-makers at the different levels (remember, these times were kept constant), and under the voice system, the message was never acknowledged. The assurance of timely processing and delivery of accurate indirect fires may have provided enough enemy suppression to allow the scouts to continue to maneuver to destroy or bypass the enemy, therefore, maintaining the initiative

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[32] The authors recognize that this is a common problem when conducting simulated combat exercises. The realization of the effects of indirect artillery or any other simulated fire power is not immediately known and therefore, receives less priority to the matters of decision-making.

and enabling the Task Force to continue the mission. In addition, there is a better than average chance that the Platoon Leader would still be alive.

5. From the time the scout element saw the enemy, reported being engaged by the enemy, requested indirect artillery fires, and finally, engaged the enemy with his own direct fire assets, 289 seconds had passed (roughly five minutes). The time saved with BMS would have been 45.7 seconds based on transmission time, since the decision time was constant.
6. The Task Force Headquarters never received a valid enemy location (grid) until 24.3 minutes had transpired (note: the transmission of the spot report lasted for two minutes after it was sent). This could have been accomplished simultaneously with BMS. It would appear that after the scouts reported being engaged by the enemy that the activity on the battlefield became the predominate factor for the decision-maker and, therefore, the enemy's grid location and size were not forwarded as a matter of preoccupation. Had BMS been available, two minutes would have been saved in transmission time that could have been used to develop alternate courses of action.
7. With BMS, the call for fire could have been received 1,340.9 seconds earlier (just over 22 minutes). This time frame coupled with the other time savings would have allowed the decision-makers time to develop an alternate plan of action that may have encompassed a coordinated activity, executed when the artillery rounds impacted.

e. The Payoffs

This example represents a common situation when conducting a movement to contact that results in a necessary Hasty Attack to neutralize the enemy. The need for an automated system such as BMS is clearly represented here. First, the rapid transmission of information throughout the tactical organization would have provided early warning sufficient to plan an alternate route, a deliberate attack using coordinated joint assets and in essence, maintain the initiative, significantly reducing battlefield losses of personnel and equipment and momentum of the battle.

The reliability of the system would ensure that messages were received and would not require retransmission. In addition, information which is seldom collected or not readily available when needed, such as grid locations, will be easily determined and transmitted accurately to all levels. With a system that provided compatibility of databases, the Scout Platoon Sergeant would have had all the information readily available upon assumption of command. This would have included mission requirements and current battlefield status and locations of all elements. Hence, a more expeditious transition and the ability to accumulate the facts necessary for more timely decision-making, at the most critical time of the conflict, would have been possible. The final point supports the contention that a key to success on the battlefield is the close integration and unity of the various combat forces involved in the AirLand Battle and the coordination of the phases of the battle. The time delays in transmitting information was so great on the FM nets that it prevented the combined arms from being a unified activity. There was no corresponding activity, at all, on the Field Artillery Battalion net. Or generally stated, the activity on one net in the combined arms does not relate to activity of the supporting arm. An automated system such as BMS will provide all points of the SIGMA STAR with real-time, accurate battlefield information, simultaneously.

Therefore, it is reasonable to validate the positive impact the system would have on the battlefield. This example provided an approximate, quantifiable perspective to the advantages recognized when an automated system was applied to an unfavorable situation that occurred primarily due to the lack of accurate intelligence available prior to the conflict and when the intelligence was available, the inability to rapidly and accurately disseminate it across the battlefield. Regardless of where they are located in the command and control hierarchy, decision-makers must deal with enormous amounts of information, plan, make assessments, issue and follow orders and then evaluate the whole process in a timely manner.

2. Example Two--Task Force Wire Obstacle

a. What Happened

During the Movement to Contact phase the elements were directed into the wadis. As the movement progressed, they received instructions to exit the wadis and deploy into a wedge formation (attack formation). It was at this time that the lead element's forward progress was halted because of a wire obstacle. Throughout the maneuver, elements were still emerging from the wadis. The following example begins with the initial notification that the wire obstacle was identified. Some of the messages were not included in our sample size because of garble, interference or override. However, enough of the message content was readable to determine the purpose.

- Message ***** -- Wire obstacle identified and reported to be passable
- Message 6/040 -- FRAGO to move into overwatch and send spot report
- Message 6/041 -- Wire obstacle confirmed; request information to be relayed to elements on left
- Message 6/042 -- Spot report forwarded with description of obstacle; Frago sent to avoid the wire obstacle and pass around it
- Message ***** -- FRAGO repeated to bypass obstacle on left and establish security on the far side
- Message 6/043 -- FRAGO repeated to move into security position and report when set
- Message 6/044 -- Notified another unit to move to the front
- Message ***** -- Enemy contact reported

- Message ***** -- FRAGO sent to engage enemy and continue to move
- Message ***** -- Equipment and personnel losses are reported; continuing to engage

b. The Results

At this point, the exchange on the battlefield became very heavy. The unit became decisively engaged and were effectively canalized by the wire obstacle and delayed long enough to be neutralized by the enemy. The communications increased and were interrupted due to the confusion created by the situation. There was equipment and personnel among the battle losses.

c. The Issues

The list below summarizes the major evaluation areas drawn from this example:

1. The unit had 116 seconds to react after the wire obstacle was initially reported.
2. The unit effectiveness was diminished as more units were bottlenecked coming out of the wadis.
3. The obstacle caused the Task Force to run into itself on the battlefield and therefore, had to rely heavily on communications to regain control.
4. The unit was delayed long enough to get entire unit decisively engaged in battle; by being fixed at the obstacle, the unit could no longer maneuver effectively and was eliminated from the Task Force's primary mission.
5. A small obstacle became a major impact on the entire Task Force by the loss of momentum, coordinated activity, and heavy losses of personnel and equipment.

d. With BMS

The following discussion provides a hypothetical analysis of the above example using a digitized system such as BMS. One assumption was that the unit was configured with existing radios, transmitting at maximum rate of 1200 bits per second. The other assumption was that the decision time decision time will remain constant.

1. The unit could have retained some combat power, allowing the Task Force to continue along an alternate route instead of losing its combat power and freedom of maneuver at the obstacle.
2. With BMS,the company commander knows, almost instantaneously, where the obstacle is.
3. Because of the connectivity of BMS, the Task Force Commander would also know, simultaneously, where the obstacle is.
4. The reaction time with BMS was only 7.7 seconds or a savings of 108.3 seconds. This time is most significant in the relaying of battlefield information than towards time spent to develop the situation and derive an alternate course of action.

5. The relaying of the battlefield information in a timely manner would have notified the elements in the wadis in sufficient time to move into overwatch positions while the decision-makers developed their courses of action.
6. The benefits received by having BMS may have saved the unit's combat effectiveness, ability to continue the mission, and saved uncounted number of personnel and equipment.

e. The Payoffs

This example provides another fitting illustration of where the lack of information or rapid dissemination of information prevented the unit from accomplishing its mission. The time delays in processing the essential information pertaining to the wire obstacle allowed the unit to lose momentum. become canalized. attrited in terms of personnel and equipment and unable to execute orders. The attributes associated with BMS provide some solutions to this situation. Generally. BMS would reduce transmission times and increase decision times. This would provide clearer, more reliable transmissions and faster reaction times.

The availability of a system that provided rapid and accurate intelligence dissemination to all appropriate levels of command would have allowed the decision-makers to select alternate routes for elements still in the wadis, or plan a course of action to break contact, or breech the obstacle and therefore. continue the mission with far less disastrous results. Rapid passing of the information would have allowed other units to react, for example, units on the flanks may have moved into position to assist the unit in breaking contact. alternate routes could have been selected and used or higher headquarters could have altered the primary missions of subordinate units. The modularity and interoperability of BMS would allow the decisionmaker to recover the battlefield information database even though critical communications equipment and vehicles were destroyed or damaged in the engagement. These characteristics are designed to give the commander every feasible assistance in integrating all of his assets in such a way that they together bring about decisive defeat of the enemy.

C. SUMMARY

It is extremely difficult to quantify degradation and enhancement effects because of command and control in combat operations. The effects of inspirational leadership and the numerous other intangibles which interact during combat operations will always be important. However, it is possible to better understand the key factors which result in success through the proper employment of new technologies and tactics. The concept of BMS offers the potential to provide the commander the capability to gain and maintain the tactical advantage and for making significant improvements in combined arms force effectiveness.

While the applications to the examples extracted from the sample were hypothetical, several observations were apparent by having the additional capability of a digitized or computerized system. These examples point out the need for a system to be timely, reliable, and accurate. By simply applying digitized values to the voice requirements, present systems are able to make significant progress on the timeliness of reporting. This real-time information provides the decision-maker more time to assess the situation and yield a decision. The reduction in actual transmission time allows for a more reliable system that is less prone to enemy electronic warfare measures. The accuracy of information is achieved by the sensors associated with the system that provides continuous update on status.

The more uncertain the combat environment the more effective command and control processes must be to ensure favorable battle resolution. Faster information exchange must be balanced with higher quality, useable battlefield information. A robust and secure communications system, such as BMS, with the capacity to transfer essential information among the force's dispersed elements in the threat environments without inhibiting, retarding or compromising the force's operations would have saved both personnel and equipment and ensured the force would be able to maintain its primary mission. This communications potential provides for the commander the ability to effectively coordinate and synchronize his combat power.

The company commanders information needs and his ability to accurately and rapidly consolidate the inputs of his subordinate elements is the crucial link in task force command and control process. A system must provide a responsive link between the commander, his subordinate and supporting commanders in every functional area of the SIGMA STAR, for example, fire support, intelligence, and combat service support. A system such as BMS would provide the commander assistance in integrating all of his assets in such a way that they, together, bring about decisive defeat of the enemy. As a result, the need for technology to enhance speed and agility in information assessment begins to rival more persuasively the need for more weapons.[33]

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[33] Several individual efforts have been documented and assimilated in Field Circular 101-34, Command and Control on the AirLand Battlefield, 1 June 1984, published by the Command and General Staff College, that provides various view on technological and humanistic aspects of integrating automation and the decision-maker in the command and control process.

X. CONCLUSIONS AND RECOMMENDATIONS

A. REVIEW

The authors' original desire in writing this thesis lay in their awareness of the discrepancy between 'what is' and 'what could be' with regard to battlefield communications. This awareness was further motivated through continued contact with the Land Battle Test Bed at Ft. Knox, KY, where the development of BMS was beginning to take shape. A survey of the studies documenting what had been done, both conceptually by the U. S. Army and in reality by industry, indicated that no parameters had yet been defined which quantified the amount and type of information necessary to support a maneuver unit engaged in combat [Ref. 2: p. B-5]. This quantification was necessary for the research on BMS to continue, resulting ultimately in the fielding of BMS. It was this obstacle in the path of the fielding of BMS that the authors' undertook to answer, hopefully contributing in a meaningful way to the realization of a system that will unquestionably contribute to realizing the standards required as expressed in the AirLand Battle doctrine. As far as the authors were concerned, research constraints were limited primarily by time and not desire. With this in mind, a smaller portion of the larger 'information requirements pie' was selected for analysis. Therefore, this thesis focused on analyzing only the voice and digital requirements and identifying the structure of the battlefield information requirements. Therefore, no attempts were made to identify requirements for sending graphics, imbedded maps, or memory requirements for the graphical displays, among others. However, several studies are identified in the text or the bibliography that derived commercial conclusions for the requirements. Several of these research efforts are still underway, and require additional exposure and support.

BMS is an electronic information gathering, processing, and distribution system, handling real-time battlefield information in a responsive manner. This system will be designed to provide for accurate information being accessible where it needs to be, on time, up-to-date, and will help realize and coordinate the AirLand Battle doctrinal objectives and the time-sensitive decisions which the execution of the battle requires. BMS, as proposed, will unstress the battlefield fighter by reducing his own involvement in the reporting process, thereby allowing more decision-making time and concentration on fighting the battle.

The primary focus of this thesis was to quantify a minimum acceptable bound on the data bit and data bit rate required for BMS. Additional emphasis was placed on developing a methodology for the efficient use of the communications tapes, recorded at NTC, in research and analytical efforts. Having derived the digital requirements from the maximum voice requirements, it is possible to project or estimate the reliability of BMS during a high intensity tactical situation once the final decision regarding the microprocessor is determined.

The data reduction process consisted of transcribing the seven VHS tapes by hand in order to provide the information necessary in a database format. Having the data in database files made it suitable for manipulating, comparing, and analyzing to establish the baseline requirements for BMS. Each of the database files could be accessed, joined, or otherwise manipulated in order to analyze a particular aspect of the content from the radio traffic and determine parameters on the requirements. Queries were established that were broken down into two general categories. The first dealt with the overall relationship of all messages within the database. The second major grouping of queries had to do with searching the database for the messages which exhibit the maximum characteristics for a given aspect of the voice-based communications, or for any particular attribute of interest to be analyzed in the database.

A research goal was to uncover the most stressful circumstances of a voice-based system, and then to evaluate those requirements against a computerized system such as BMS to determine the impact that such a system may have on the modern battlefield. Prior to any attempt to determine the digital requirements of a system, it was necessary to establish a profile of the voice requirements for the selected sample. To achieve the peak stress points, the authors' maximized the output of the queries. The first step was to identify an unplanned, spontaneous event. Next, it was necessary to identify the maximum characteristics for each frequency. A comparison of the seven frequencies was made, and the maximum output for each category was considered. By analyzing the sample size for the maximums of the maximums, the highest level of stress on the communications systems was achieved. The last step was to digitize the voice requirements. The results indicated that our communications model was within expectations for the mission selected and while the sample size was limited, it provided values that could be used to derive the digital requirements.

The highest character per second transfer rate was used to quantify the information exchange rates. This value was then compared to the maximum rate possible with the existing system. The data bit requirements necessary to support company-level tactical operations were defined by the sizes of the reports used most frequently during the Hasty Attack. Two methods were used to identify report sizes. For the first method, values were extracted from the type report with the maximum characters determined by the actual voice messages. For the second method, a study conducted by CECOM and the Signal Center (see Chapter Eight, above) assisted the effort. Each report was categorized by type and each maximum bit length was recorded. The values were taken from the type report in each category with the maximum characters.

With the emphasis on command and control, the digital requirements were applied to two examples extracted from the sampled unit's simulated combat exercise conducted at NTC. While the applications provided a hypothetical analysis of the effects a system such as BMS would have made, several observations were apparent. The examples identified a need for a system that was timely, reliable, and accurate. The integration of automation and communications demonstrated a tremendous potential for resolving current problems regarding the accuracy, accessibility, timeliness, and integrity of battlefield information. Because everyone will have the same 'view' of the battlefield, and because data will be updated automatically through hardware and software protocols, decisions will be based upon the best information available. This communications potential provides for the decision-maker the ability to effectively coordinate and synchronize his combat power.

B. CONCLUSIONS

From the research effort, the authors were able to develop conclusions that are valuable to future studies and implementation of BMS. These conclusions are supported with considerations and recommendations that were not established from the results of our findings but were identified throughout the research effort in general. Other studies are available to provide more discussion on the considerations listed. The listing of the conclusions and considerations are provided below.

- The time lag or time delay associated with normal voice transmissions on FM radios prevented the combined arms from executing as a unified activity. Activity on one net in the combined arms team did not relate to the activity on the net of a supporting arm.
- The application of digital equipment to solve battlefield reporting and information processing requirements is a realistic, obtainable goal.

- Much of the required hardware already exists in the commercial market, and their application towards solving military requirements requires continued research and exploration.

- A system with the requirements proposed by BMS will resolve current problems regarding the accuracy, timeliness, and reliability of information. Decision-making will be significantly enhanced by the availability of updated, real-time information to all units within the SIGMA STAR.

- A key to success on the modern battlefield is the close integration and unity of the various combat forces involved in the AirLand Battle and the coordination of the phases of the battle. This coordination is enhanced by BMS.

- The need for technology to enhance the speed and the agility of the information flow and assessment process begins to rival more persuasively the need for more weapons. Information is a weapon.

- Regardless of where they are located in the command and control hierarchy, decision-makers must deal with enormous amounts of information from which they plan, make assessments, issue orders, and then evaluate the whole process.

- Survivability issues pertaining to an automated system on the battlefield include:

  (1) Protection, hardening, mobility and redundancy

  (2) Modularity

  (3) Reliability, ease of operation and logistical supportability

  (4) Electronic counter-countermeasure capabilities, and protection against electromagnetic pulse and ionospheric disturbances

- By simply providing the means to digitize the current voice system, significant improvements were recognized in message throughput, which provides more time to the decision-maker, enabling him to make better decisions earlier than before on the battlefield.

1. Considerations

a. Technical

Technical considerations were developed throughout the research effort. These considerations reflected future possibilities that were identified from studies and sources that contributed indirectly to the authors' research. These technical aspects were determined to be valuable in continued research and implementation of BMS.

- Future considerations for equipment improvements and personnel reductions will most likely benefit from having BMS in place. Any reduction in crew-size (like the introduction of an automatic loader onto a tank) will be offset if BMS is already on-board to assist the remaining crewmembers with the communication requirements.

- People in general, including soldiers, are generally apprehensive about accepting new technological concepts. This is principally caused by a lack of understanding and inexperience. The most obvious conclusion from this observation is the reality that now is the time to prepare soldiers for the high-tech battlefield of the future. Training programs should be established to begin development of technological literacy and hands-on familiarization of prototypes or off-the-shelf products. Getting BMS into the hands of its future users now is mandatory.

- The advent of time-saving, automated communications systems does not imply we will communicate less because of the omission of repeated messages and long, unformatted reports. Rather, it implies that we will communicate differently as a result of our being more informed than before.

- Subordinate commanders must have a continuous flow of information from the commander for guidance to the sensors and weapons, from the sensors to target planners and from target planners to the delivery systems.
- The skillful use of resources requires timely and responsive working relationships between the respective combat forces which emphasizes the need for a responsive communications system.
- The command and control system would need a common database architecture to be fully integrated. This would require integrated software design and standardized information-handling from one functional community to the next. If each community develops its own hardware components and software support packages independently, as has been the case in the past, this interface and integration problem becomes almost unmanageable.
- The amount of time saved with BMS may be most readily recognizable in circumstances which require the greatest amount of time now, like the planning or the consolidation phases of a combat operation. BMS might eliminate typical command meetings that draw subordinate commanders from the battle area for planning, and would allow more planning and preparation to occur at the battlefield itself.
- Too much information can be worse than too little. Equipment which makes information available in quantity must also make it possible to quickly sort out that which is important. Without such a feature, the decisionmaker is usually better off with manual methods.

b. Humanistic

The humanistic aspects of the research effort were not evaluated and therefore lent no quantifiable merit to our conclusions. However, the authors' conclude that it is simply not enough to evaluate how technological advances will assist a decision-maker in the command and control environment of a dynamic battlefield. Rather, an evaluation must be conducted to establish how the total concept of execution on the battlefield changes. An important aspect includes the humanistic approaches to the introduction of new technology, the degree of acceptance, the confidence level, and the adaptability to different user styles, among others. Within this arena, the following conclusions are provided:

- Every effort should be made to involve the commander or decision-maker in the evolution of the automated communications system.
- Many of the problems associated with command and control are rooted in habit and custom, or derived from instinctive ways of operating. These problems must be addressed or any technological advance may not achieve the desired results.
- A commander who is given his mission and the intent of his superior commander, who has the authority to decide how to operate within that mission and intent, and thoroughly understands the requirements involved to accomplish the mission and intent will be quicker and more effective on the battlefield, whatever the medium of information flow.
- Uncertainty is normal in warfare. Information flow in quantity is not an automatic cure for uncertainty.

- The generation of battlefield information must not be burdensome to any commander. A system which relies on information generated by commanders must give those same commanders an incentive for providing such information, a guarantee that they will benefit.
- The availability of detailed information must not tempt a commander to demand more detail than he needs, or to issue orders which are properly matters for his subordinates to decide.
- The concepts involved in such a system entails an extraordinary level of mutual trust and confidence throughout the force that information shared will be properly used toward mission accomplishment in accordance with the governing concept and will be denied the enemy.
- The impact on the chain of command structure and confidence in subordinates' abilities must be heavily evaluated when a commander has the opportunity to monitor subordinates' status and override the end result of the their decision-making.
- In addition, such a system capable of "skip echelon" reporting may erode a fundamental principle of orders flowing through the chain of command.
- Technological complexity can be accepted if the actual working of the system is made simple to the user and system reliability is assured.
- Much attention needs to be focused on the machine-to-man interface to allow any BMS initiative to be adaptable to the commander using it.
- The design must be adaptable to the "personal" style of the decision-maker, within reasonable guidelines.
- Attempts to automate communications with the emphasis on command and control should focus design from the decision-makers up, not from the electronics capabilities down.

2. Recommendations

The authors' recommendations are based upon experience, common sense, and the results of the research effort. The implementation of many of these recommendations may be difficult and in some cases may not appear to be cost-effective. However, the impact of BMS on the dynamic battlefield, its ability to provide control to overcome fear, and the acceptance of it by all echelons of the tactical organization, may outweigh the disadvantages of each of these recommendations.

a. Technical

The design of BMS should be oriented towards increasing the accuracy, reliability, and speed of processing data through the use of end-to-end message verification schemes and repeaters to extend the communication ranges of the radios. To achieve these capabilities the system should reflect design characteristics which provide for BMS being durable and survivable, given the environment (both friendly and hostile) within which it is to operate. Flexibility, modularity, interoperability, and compatibility all rank high on the list of desired features, including design features which permit continuous operations as well as electronic warfare and counter-countermeasures. Other technical characteristics are listed below:

- Common databases should have the capability to be updated from high to low, and low to high automatically in a fashion transparent to the user.
- Should be compatible with ACCS software and hardware protocols.
- Need to provide protection against both power loss and power surges with clean power through some back-up power that is clean and uninterruptable. BMS should not have to be shut-off to start the vehicle.
- Each system should have identical capabilities or the ability to switch to a required database that is needed by the decision-maker should his own system become disabled.
- The system design, and more specifically, the graphics and menus design, should be layered and based upon the fact that different functional tasks are performed during different phases of the battle.
- The system should include a feature that provides for automatic changing of frequencies at specified times.
- A design feature should provide for passive identification of friendly forces.
- FM voice should remain as the backup (or override) method and therefore, the design should permit the capability to switch options without difficulty.
- Needs the ability to conduct multiple simultaneous target handoffs. Or stated in another way, if one system/one sensor identifies a target that cannot be identified by other elements, the system should be able to retain target data integrity while transferring the data to the other elements.

b. Humanistic

No system is complete if it doesn't conform to the humanistic interfaces of the system. While the technical recommendations provide the basis for further research and implementation of BMS, the system's acceptability and the user's confidence will be severely degraded without the system's capability to adapt to the various characteristics of the decision-makers and users at each node. It should be emphasized that these recommendations are general in nature since our focus was not in this area, and therefore, further analysis should be expected. Furthermore, significant problems should be anticipated with the implementation of these interfaces. However, this element of BMS development and integration into the battlefield should not hinder the overall requirement to provide a reasonable system prototype to the user for near-term training and transition to the highly technical battlefield of the future.

- The design should be capable of handling different kinds of command and control problems, such as optimum decision selection, forecasting, planning, targeting, and evaluation.
- Given short decision time, a conceptually strong but mathematically weak user who is making frequent input mistakes, system design should increase graphic, symbolic, and allegorical displays, and slow the interaction pace.

- If a user is slow to conceptualize but quick to form logical relationships, the the system design should require more numeric input.
- If a user is behaving unconventionally, then the system design should repeat sequences, in order to "check" the user's coherence and logic.
- If a command and control decision problem is characterized by short time and high stakes, the system design should use color, blink and be fast paced.

C. SUMMARY

Existing methods which strive to improve communications and to report accurate information on the battlefield were discussed, including shortfalls when to the desired capabilities of BMS. Background studies of BMS were reviewed and the system requirements identified. Assumptions and methodology which framed our research effort provided assistance in future studies. A description of the raw data and the variables utilized in modelling the information flow was presented. The authors then defined the voice requirements for the passage of battlefield information. The validity of our basic model upon which the data bit and data bit rates depend was accomplished. The voice requirements were then digitized to establish the data bit and data bit rate minimum acceptable bounds and various trade-offs associated with the system. The data bit and data bit rate was applied to our sample using selected events that encompassed the spectrum of our goals. The potential advantage of a system such as BMS for the dynamic battlefield was demonstrated. Finally, the conclusions and recommendations that surfaced during the research effort were discussed.

One of the many goals of this thesis was to provoke continued research and provide greater visibility on the positive impact that a system like BMS will have upon units in the field. Our focus was on the tactical aspects of maneuver units. To continue the effort, analysis should concentrate on other areas such as the interoperability within the components of the SIGMA STAR, logistical communications architecture, message protocols, software engineering, geographical filters, symbology, systems architecture and interfaces, the soldier-machine interface, doctrinal implications, and what should be maintained in resident memory.[34]

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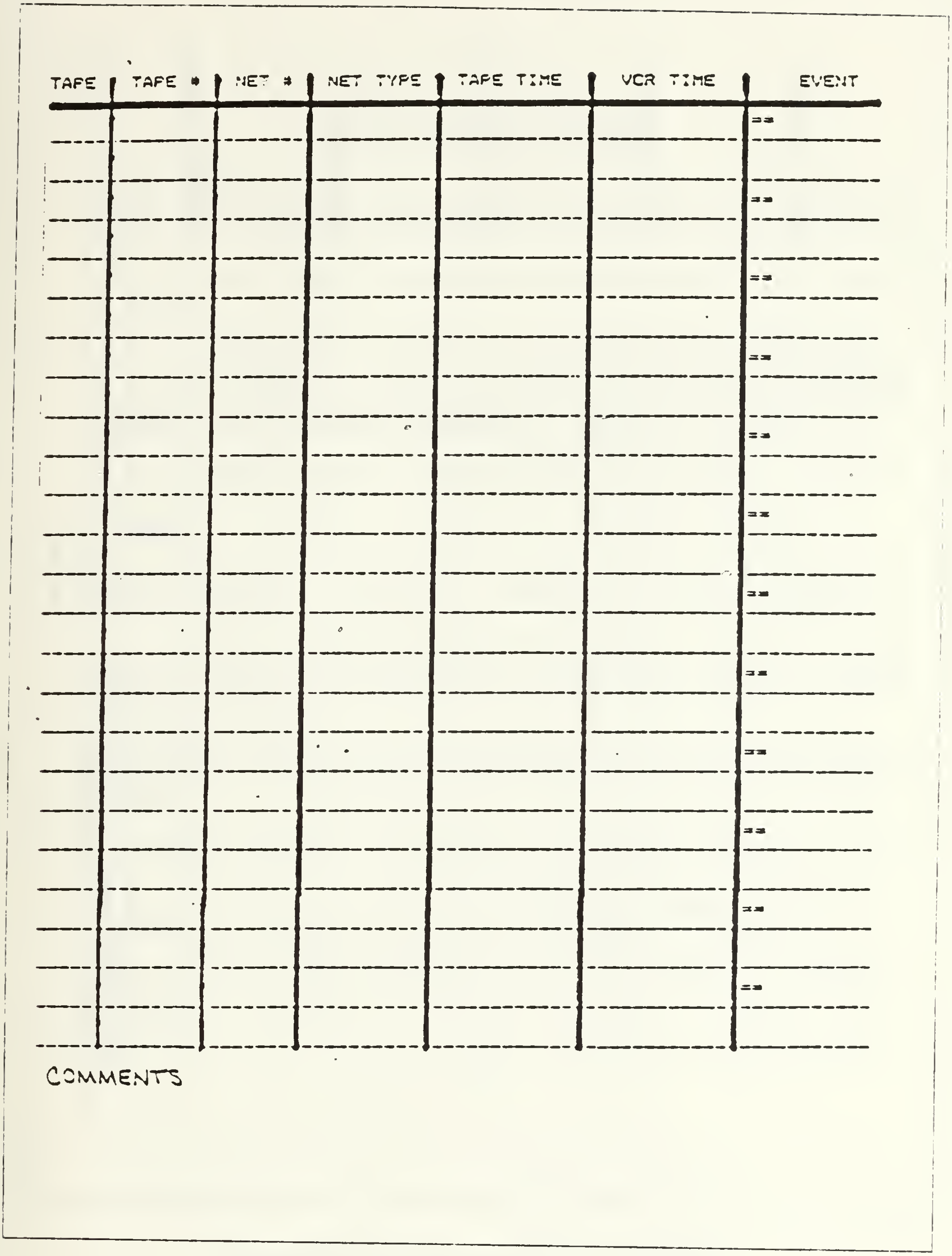
[34] Numerous articles have been written and published by other authors who have devoted time and effort in researching and analyzing the various aspects of automation and telecommunications on the battlefield. The credit for some of the above conclusions and recommendations should be assigned to the writers who included their work in Field Circular 101-34, *Command and Control on the AirLand Battlefield, Selected Readings*, U. S. Army Command and General Staff College, Fort Leavenworth, KS, June 1984. This circular also offers many other articles that are both informative and thought provoking for the reader concerned with the future direction of the AirLand Battlefield.

APPENDIX A
FORMS SUPPORTING DATA COLLECTION

The two forms utilized by the authors to collect and organize the data for the thesis are provided on the following pages. The Data Record Sheet is self-explanatory, being nothing more than columns functionally organized to provide symmetric blanks within which to enter the appropriate data. The form was used to keep a record, first of all, of the identity of the segments of the original tapes from which the VHS tapes were created and, secondly, to provide the analyst a place to record significant tactical observations which might be useful later on. Acceptable entries for each column are discussed below:

- Tape: Identifies whether the recording came from the Granite (G) or the Tiefort (T) Mountain relaying station.
- Tape #: Used to record the number of the tape as developed by the Army Research Institute (ARI) Field Site, Monterey, CA, as they archived the tapes and cataloged them.
- Net #: Used to record the number of the net being taped/monitored. The numbers were the numbers from the front of the 40-channel Veritrac Model 5000 Dictaphone Voice Playback System, also recorded by ARI Field Site, Monterey.
- Net Type: Used to indicate the type of net being monitored, i.e., whether it was a Battalion Command net, or a Scout net, or a Company net.
- Tape Time: Used to record the time displayed on the 40-channel Veritrac Model 5000 Dictaphone Voice Playback System in order to ensure that segments off-set in time and tape reel number could be properly joined together in a manner which preserved the proper time sequencing.
- VCR Time: Used to record the counter number for the VHS used to provide a continuous flow of radio communications from the skewed segments available for use from ARI. Provided a means of easy access to significant events on the finished product.
- Event: Used to record an event of tactical or operational significance as determined by the analyst for further review if necessary.

The backside of the Data Worksheet/Evaluation Form (Figure A.3) contains the instructions for the proper utilization of that form. Note that the form calls for accuracy to one-tenth of a second with regard to the timing issues. The form is subdivided into several different sections horizontally so that each section can be used to capture the data structure of a particular message, which was the level of focus of this thesis.



TAPE	TAPE #	NET #	NET TYPE	TAPE TIME	VCR TIME	EVENT
						==
						==
						==
						==
						==
						==
						==
						==
						==
						==
						==
						==

COMMENTS

Figure A.1 Data Record Sheet.

CALLSIGNS					MESSAGES					
TIME INITIATED	CALLING CALLSIGN	CALLED CALLSIGN	TIME COMPLETED	MESSAGE HEIRARCHY	TIME MESSAGE COMPLETED	MESSAGE TOTAL LENGTH	CHARACTERS PER MESSAGE	TYPE OF REPORT	MESSAGE FORMAT	ACTIVITY PHASE

TRANSCRIBED MESSAGE:

TRANSCRIBED MESSAGE:

TRANSCRIBED MESSAGE:

TRANSCRIBED MESSAGE:

TRANSCRIBED MESSAGE:

Figure A.2 Data Worksheet/Evaluation Form.

EVALUATION FORM INSTRUCTIONS

A. CALLSIGNS:

1. TIME INITIATED: TIME STARTS WHEN CALLING STATION MAKES FIRST ATTEMPT TO CONTACT THE CALLED STATION (DATE TIME GROUP IN TENTHS OF A SECOND)

2. CALLING CALLSIGN: CALLSIGN OF THE STATION INITIATING THE CALL (AS STATED)

3. CALLED CALLSIGN: CALLSIGN OF THE STATION CALLED (AS STATED)

4. TIME COMPLETED: TIME ENDS WHEN CALLED STATION ACKNOWLEDGES THE CALL AND A POSITIVE CONNECTION BETWEEN THE TWO STATIONS IS MADE OR THE CALLED STATION CANNOT BE REACHED AND THE CALLING STATION BREAKS CONNECTION (DATE TIME GROUP IN TENTHS OF A SECOND)

*5. MESSAGE HEIRARCHY: DEPICTS THE MESSAGE FLOW FROM THE CALLING STATION TO THE CALLED STATION [HEIRARCHY OF MESSAGE]

B. MESSAGES:

1. TIME MESSAGE COMPLETED: TIME ENDS WHEN THE CALLING STATION COMPLETES MESSAGE -- IDENTIFIED BY PROWORD "OUT" (DATE TIME GROUP IN TENTHS OF A SECOND)

2. MESSAGE TOTAL LENGTH: COMPUTED DURATION OF THE TOTAL MESSAGE WHICH IS THE TOTAL DIFFERENCE BETWEEN THE DATE TIME GROUPS -- [TIME MESSAGE COMPLETED - TIME INITIATED = MESSAGE TOTAL LENTGH] (RECORDED IN TENTHS OF A SECOND)

3. CHARACTERS PER MESSAGE: ASSUMING THE BODY WAS SENT BY ELECTRONIC MEANS, THE CONTEXT OF THE MESSAGE BODY WILL BE TRANSCRIBED AND EACH CHARACTER OR SPACE WILL BE COUNTED AND ITS NUMERICAL EQUIVALENT RECORDED

**4. TYPE OF REPORT: MESSAGES WILL BE GROUPED INTO ONE OF FOUR MAJOR TYPES -- CONTACT(C), SPOT(S), CALL FOR FIRE(CFF), FRAGO(F)

**5. MESSAGE FORMAT: SPECIFY WHETHER THE MESSAGE CONTENT WAS ORGANIZED INTO A FORMATTED REPORT (F) OR UNFORMATTED REPORT (U)

**6. ACTIVITY PHASE: DETERMINE THE CURRENT ACTION OF THE UNIT IN RELATION TO THE OVERALL MISSION PHASE -- ATTACKING, IN POSITION, MOVING, ETC

*OMIT **OPTIONAL -- IF IT CAN BE DETERMINED

Figure A.3 Evaluation Form Instructions.

APPENDIX B
RAW DATA VALUES

The tables which follow list the raw data values as entered in the database and is the data upon which the conclusions of this thesis rest. The meaning of the content of each attribute is provided in Chapter Six, above, and a discussion of the possible data values for each is provided below:

- Frequency Number (FREQ NO): values one through seven may be entered here, and is assigned to each frequency selected for inclusion in the database.
- Message Number (MSG NO): values beginning at one and ascending until the end of the messages, by frequency, are entered here. The highest number of messages recorded on any frequency was 184.
- START TIME: the length of time, in seconds, from the start of the tape to the time the calling station initiated his attempt(s) to contact someone else.
- Communication Established (COMMO ESTAB): the time, in seconds, from the start of the tape to the time the called station acknowledged the call or when the called station cannot be reached and the calling station ceases his attempt(s) is recorded here.
- STOP TIME: the time, in seconds, from the start of the tape to the time the two communicating stations ceased communication, is recorded here.
- TOTAL TIME: the time, in seconds, that the message took to relay from one station to the next is recorded here. It represents the difference, in seconds, between the values in the START TIME and the STOP TIME columns.
- Message Flow (MSG FLOW): indicates the flow of information pertinent to the battle. It was either up (U), down (D), or undetermined (X).
- Content Analysis (INFO RQMT): whether or not the message relayed contained any information pertinent to the battle is indicated in this column. Entries were either yes (Y), or no (N).
- Number of Characters Per Message (CHAR/MSG): numbers in this column reflect a count of the number of characters required to relay the information contained in each message.
- Type of Report (TYPE REPT): entries in this column reflected the authors' judgement as to the type of report the information could have been sent in if a doctrinally formatted report were used. Choices included a spot report (S), a frago (F), a call for fire (CFF), a contact report (C), or an undetermined choice (U).
- ACTIVITY: entries in this column reflected the authors' judgement as to the activity of the unit at the callsign level (i.e., at the platoon or company level, but NOT at the individual vehicle level) at the time the message was sent. Entries included either moving (M), in position (IP), attacking (A), initial contact with enemy forces (C), or an undetermined choice (U).

NATIONAL TRAINING CENTER TAPES

FREQUENCY ONE

FREQ NO	MSG NO	START TIME	COMMO ESTAB	STOP TIME	TOTAL TIME	MSG FLOW	INFO RQMT	CHAR/ MSG	TYPE REPT	ACTIVITY
1	001	132		135	3	D	Y	55	S	M
1	002	148		154	6	D	Y	57	F	M
1	003	181		183	2	D	Y	35	U	M
1	004	282	288	304	22	D	Y	222	C	M
1	005	553	562	608	55	U	Y	377	C	C
1	006	610	615	651	41	D	Y	476	C	M
1	007	804	818	820	16	D	Y	61	F	M
1	008	834	839	860	26	X	Y	196	C	M
1	009	865		877	12	D	Y	165	F	M
1	010	886		890	4	D	Y	57	F	M
1	011	926	946	960	34	D	Y	192	C	M
1	012	987	992	1006	19	U	Y	261	C	M
1	013	1013		1025	12	D	Y	79	C	M
1	014	1073		1075	2	D	Y	30	F	M
1	015	1096		1099	3	D	Y	38	F	M
1	016	1114	1130	1148	34	X	Y	245	S	M
1	017	1232		1234	2	D	Y	53	F	M
1	018	1298	1313	1321	23	D	Y	105	F	M
1	019	1787		1794	7	D	Y	99	F	M
1	020	1831		1835	4	X	Y	68	S	M
1	021	1839		1844	5	X	Y	94	S	M
1	022	1846		1853	7	X	N	37	S	M
1	023	1858		1865	7	U	Y	28	S	M
1	024	1868		1870	2	D	Y	24	F	M
1	025	1907		1909	2	D	Y	15	F	M
1	026	1946		1953	7	D	Y	99	F	M
1	027	1964		1969	5	D	Y	102	F	M
1	028	2003		2010	7	D	Y	132	S	M
1	029	2041		2050	9	D	Y	94	F	M
1	030	2061		2070	9	D	Y	143	F	A
1	031	2146		2150	4	U	Y	46	S	C
1	032	2152		2156	4	D	Y	71	F	C
1	033	2158		2170	12	U	Y	65	S	C
1	034	2174		2177	3	D	Y	37	F	C
1	035	2292		2298	6	U	Y	74	CFF	C
1	036	2400	2405	2420	20	U	Y	214	S	A
1	037	2445		2447	2	X	Y	21	F	A
1	038	2525		2577	47	D	Y	169	S	A
1	039	2633		2635	2	X	Y	22	F	M
1	040	2747		2754	7	D	Y	71	F	M
1	041	2757	2761	2767	10	U	Y	57	F	M
1	042	2788	2813	2824	36	U	Y	117	S	M
1	043	2861		2867	6	U	Y	86	F	M
1	044	2870	2886	2889	19	D	Y	126	S	M
1	045	2899		2917	18	U	Y	248	F	A

Figure B.1 Frequency One Raw Data Values.

NATIONAL TRAINING CENTER TAPES

FREQUENCY ONE

FREQ NO	MSG NO	START TIME	COMMO ESTAB	STOP TIME	TOTAL TIME	MSG FLOW	INFO RQMT	CHAR/ MSG	TYPE REPT	ACTIVITY
1	046	2938		2945	7	U	Y	148	S	A
1	047	3072		3082	10	D	Y	154	U	C
1	048	3101		3105	4	X	Y	49	S	A
1	049	3113		3119	6	D	Y	40	S	C
1	050	3132		3142	10	D	Y	102	S	M
1	051	3152		3183	31	U	Y	129	F	A
1	052	3508	3518	3618	110	U	Y	795	C	M
1	053	6035	6052	6089	54	U	Y	323	S	M
1	054	6521		6527	6	X	Y	69	S	C
1	055	6937		6947	10	X	Y	79	S	M
1	056	7329	7394	7423	94	U	Y	243	U	M
1	057	8746	8757	8827	81	X	Y	271	S	M
1	058	8851	8892	8940	89	U	Y	347	S	M
1	059	9055	9173	9197	132	U	N	175	S	M
*** Total ***					1227			7987		

Figure B.2 Frequency One Raw Data Values, Continued.

NATIONAL TRAINING CENTER TAPES

FREQUENCY TWO

FREQ NO	MSG NO	START TIME	COMMO ESTAB	STOP TIME	TOTAL TIME	MSG FLOW	INFO RQMT	CHAR/ MSG	TYPE REPT	ACTIVITY
2	001	1025	1032	1039	41	D	Y	164	S	IP
2	002	1040		1044	4	D	Y	42	F	M
2	003	1148	1168	1184	36	U	Y	167	S	IP
2	004	1241	1247	1256	15	D	Y	169	C	M
2	005	1276	1283	1307	31	U	Y	192	S	IP
2	006	1525	1534	1551	26	D	Y	144	C	IP
2	007	1552	1555	1586	35	U	Y	160	C	M
2	008	1819	1851	1878	59	U	Y	282	S	IP
2	009	1886		1904	18	X	Y	27	S	IP
2	010	1936	1944	1948	12	U	Y	98	C	A
2	011	2132		2134	2	D	Y	33	F	M
2	012	2252	2268	2321	69	U	Y	309	S	M
2	013	2353	2359	2363	10	D	Y	73	F	M
2	014	2396		2408	12	D	Y	72	F	M
2	015	2578		2584	6	X	Y	99	F	A
2	016	2807		2846	7	D	Y	39	F	M
2	017	2864		2876	12	D	Y	86	F	M
2	018	3159		3164	5	X	Y	49	F	A
2	019	3206		3212	6	D	Y	87	F	M
2	020	3394		3396	2	D	Y	27	F	A
2	021	6027	6040	6047	20	D	Y	92	F	IP
2	022	6168	6177	6196	28	U	Y	170	C	M
2	023	6200	6320	6351	151	U	Y	291	S	C
2	024	6746	6750	6772	26	D	Y	262	S	M
2	025	6857	6868	6880	23	D	Y	269	F	A
2	026	6905	6913	6916	11	D	Y	74	F	A
2	027	6921	6928	6935	14	U	Y	98	F	A
2	028	7031		7036	5	X	Y	87	F	C
2	029	7113		7125	12	D	Y	42	F	M
2	030	7631		7634	3	D	Y	57	F	A
2	031	7716		7723	7	U	Y	59	S	C
2	032	7738		7745	7	D	Y	122	F	M
2	033	7938		7942	4	D	Y	89	F	M
2	003	8203		8212	9	U	Y	63	S	C
2	035	8314		8316	2	D	Y	17	F	M
2	036	8333		8336	3	D	Y	40	F	M
2	037	8673		8683	10	U	Y	88	S	C
2	033	8731	8743	8790	59	U	Y	150	S	C
2	039	8791	8798	8983	272	U	Y	716	S	C
*** Total ***					1074			5105		

Figure B.3 Frequency Two Raw Data Values.

NATIONAL TRAINING CENTER TAPES

FREQUENCY THREE

FREQ NO	MSG NO	START TIME	COMMO ESTAB	STOP TIME	TOTAL TIME	MSG FLOW	INFO RQMT	CHAR/ MSG	TYPE REPT	ACTIVITY
3	001	102	116	159	57	X	Y	283	U	U
3	002	1454	1461	1466	12	X	N	96	S	U
3	003	1511	1543	1554	43	U	Y	265	U	U
3	004	1882	1891	1896	14	X	N	102	U	U
3	005	2123	2142	2166	43	X	Y	340	S	U
3	006	2486	2493	2516	30	U	Y	206	S	U
3	007	2695	2737	2759	64	X	N	192	U	U
3	008	3010	3093	3228	218	U	Y	792	S	IP
3	009	6283	6314	6379	96	X	Y	343	CFF	U
3	010	6534		6705	328	U	Y	563	S	U
3	011	6710	6869	6977	267	X	Y	1381	C	IP
*** Total ***					1172			4563		

Figure B.4 Frequency Three Raw Data Values.

NATIONAL TRAINING CENTER TAPES

FREQUENCY FOUR

FREQ NO	MSG NO	START TIME	COMMO ESTAB	STOP TIME	TOTAL TIME	MSG FLOW	INFO RQMT	CHAR/ MSG	TYPE REPT	ACTIVITY
4	001	773	781	787	14	D	Y	148	U	M
4	002	806	811	912	106	U	Y	805	C	M
4	003	914		926	12	D	Y	104	F	M
4	004	932		934	2	X	N	28	S	M
4	005	1056		1089	33	D	Y	385	F	M
4	006	1192	1196	1204	12	U	Y	150	F	M
4	007	1208		1212	4	D	N	25	U	M
4	008	1251		1259	8	U	Y	53	F	M
4	009	1293		1376	83	U	Y	808	U	M
4	010	1617	1625	1636	19	U	Y	108	S	C
4	011	1710	1716	1737	27	X	Y	187	F	M
4	012	1836	1843	1858	22	D	Y	210	F	M
4	013	1885	1894	1906	21	U	Y	187	U	M
4	014	2051	2059	2077	26	U	Y	181	S	IP
4	015	2078	2082	2096	18	D	Y	197	S	IP
4	016	2096		2106	10	D	Y	152	F	M
4	017	2117	2124	2139	22	D	Y	188	S	M
4	018	2144	2150	2164	20	X	Y	161	U	M
4	019	2167		2200	33	H	Y	369	S	IP
4	020	2268	2273	2292	24	X	Y	202	F	M
4	021	2325	2329	2353	28	D	Y	187	F	M
4	022	2486		2490	4	D	Y	55	F	M
4	023	2499	2509	2522	23	D	Y	180	F	M
4	024	2526		2533	7	D	Y	111	F	M
4	025	2652		2672	20	D	Y	215	S	M
4	026	2706		2727	21	U	Y	237	S	M
4	027	2842		2863	21	U	N	35	U	M
4	028	2884	2899	2940	56	D	Y	356	F	M
4	029	2952		2971	19	U	Y	72	S	M
4	030	3011	3019	3049	38	D	Y	293	C	M
4	031	3050	3057	3076	26	D	Y	260	F	M
4	032	3353		3383	30	U	Y	173	C	M
4	033	3562		3571	9	D	Y	96	F	M
4	034	3892		3901	9	D	Y	78	F	A
4	035	3915	3920	3943	28	D	Y	156	F	A
4	036	4005		4010	5	U	N	31	S	A
4	037	4040		4043	3	D	Y	32	F	A
4	038	4051		4054	3	D	N	32	F	A
4	039	4059		4065	6	U	Y	76	S	A
4	040	4066	4075	4078	12	U	Y	138	S	A
4	041	4164	4187	4214	50	U	Y	343	S	A
4	042	4283	4289	4304	21	U	Y	95	S	A
4	043	4551		4576	25	U	Y	230	C	A
4	044	4578	4617	4619	41	X	Y	94	S	A
4	045	4679	4682	4692	13	D	Y	99	U	A
4	046	4752		4781	29	X	N	47	S	A

Figure B.5 Frequency Four Raw Data Values.

NATIONAL TRAINING CENTER TAPES

FREQUENCY FOUR

FREQ NO	MSG NO	START TIME	COMMO ESTAB	STOP TIME	TOTAL TIME	MSG FLOW	INFO RQMT	CHAR/ MSG	TYPE REPT	ACTIVITY
4	047	4866		4868	2	H	N	26	S	A
4	048	4869	4875	4898	29	D	Y	219	F	IP
4	049	4936	4941	4962	26	H	Y	331	F	IP
4	050	4986	4994	5049	63	U	Y	706	S	IP
4	051	5096		5109	13	H	N	73	U	IP
4	052	5370	5375	5385	15	H	N	179	U	IP
4	053	5496	5502	5524	28	U	Y	304	S	IP
4	054	5598		5634	36	U	Y	234	S	IP
*** Total ***					1275			10441		

Figure B.6 Frequency Four Raw Data Values, Continued.

NATIONAL TRAINING CENTER TAPES

FREQUENCY FIVE

FREQ NO	MSG NO	START TIME	COMMO ESTAB	STOP TIME	TOTAL TIME	MSG FLOW	INFO RQMT	CHAR/ MSG	TYPE REPT	ACTIVITY
5	001	175	180	195	20	X	Y	187	F	M
5	002	224	236	297	73	U	Y	398	C	M
5	003	409	422	440	31	U	Y	293	F	M
5	004	555	570	571	16	U	Y	131	S	M
5	005	730	743	769	39	H	Y	322	S	M
5	006	959	964	985	26	U	Y	201	S	M
5	007	994	997	1054	60	U	Y	272	S	M
5	008	1118	1123	1219	101	U	Y	604	S	M
5	009	1312	1316	1329	17	H	Y	142	U	M
5	010	1374	1377	1408	34	X	Y	168	S	M
5	011	1411	1413	1457	46	U	Y	252	S	M
5	012	1843	1866	1880	37	H	Y	150	U	M
5	013	1881	1886	1901	20	U	Y	178	U	M
5	014	1902		1909	7	X	Y	49	U	M
5	015	2703		2706	3	X	Y	28	C	M
5	016	9538	9550	9557	19	X	Y	99	F	M
5	017	9579	9586	9590	11	X	Y	99	U	M
5	018	9612	9618	9623	11	X	Y	83	U	M
5	019	9704		9740	36	H	Y	265	F	M
5	020	9802	9819	9826	24	H	Y	158	S	M
5	021	9826		9835	9	U	Y	80	S	M
5	022	9877		9885	8	D	Y	84	F	M
5	023	9906	9937	9951	45	H	Y	196	S	M
5	024	10061	10066	10073	12	D	Y	92	F	M
5	025	10134		10140	6	D	Y	50	CFF	A
5	026	10174	10181	10193	19	X	Y	155	S	M
5	027	10233		10239	6	U	Y	76	F	M
5	028	10241	10246	10263	22	H	Y	187	U	M
5	029	10306	10310	10330	24	U	Y	239	C	M
5	030	10338	10358	10409	71	H	Y	436	U	M
5	031	10410	10417	10430	20	H	Y	180	S	M
5	032	10466	10520	10562	186	U	Y	1022	C	M
5	033	10563		10571	8	U	Y	72	S	M
5	034	10822		10847	25	X	Y	267	U	M
5	035	10934	10940	10959	25	D	Y	257	C	M
5	036	11078	11082	11100	22	H	Y	176	F	M
5	037	11105	11116	11175	70	U	Y	290	S	A
5	038	11191	11204	11237	46	U	Y	345	F	A
5	039	11411	11416	11424	13	D	Y	125	U	A
5	040	11455	11459	11469	14	D	Y	130	F	A
5	041	11476	11480	11503	27	D	Y	263	U	A
5	042	11530	11535	11560	30	U	Y	276	F	A

Figure B.7 Frequency Five Raw Data Values.

NATIONAL TRAINING CENTER TAPES

FREQUENCY FIVE

FREQ NO	MSG NO	START TIME	COMMO ESTAB	STOP TIME	TOTAL TIME	MSG FLOW	INFO RQMT	CHAR/ MSG	TYPE REPT	ACTIVITY
5	043	11708	11712	11727	19	U	Y	114	S	A
5	044	11812		11820	8	U	Y	71	S	A
5	045	11821	11830	11834	13	U	Y	74	S	A
5	046	11851	11854	11870	19	U	Y	226	S	A
5	047	11871	11889	11891	20	U	Y	188	C	A
5	048	11917	11926	11936	19	H	Y	136	F	A
5	049	11939	11947	11974	35	D	Y	248	U	A
5	050	11997	12001	12057	60	U	Y	623	C	A
5	051	12072	12081	12088	16	U	Y	100	U	A
5	052	12121	12131	12142	21	H	Y	132	U	A
5	053	12143	12148	12150	7	X	Y	52	U	A
5	054	12157		12166	9	X	Y	88	F	A
5	055	12167	12169	12223	56	D	Y	428	U	A
5	056	12281	12293	12339	58	U	Y	267	S	A
5	057	12357	12361	12369	12	H	Y	147	S	M
5	058	12401	12403	12442	41	H	Y	327	S	C
5	059	12495	12510	12617	122	D	Y	728	U	A
5	060	12621	12625	12647	126	H	Y	276	S	A
5	061	12650	12653	12705	55	U	Y	551	C	A
5	062	12706	12709	12716	10	D	Y	107	F	A
5	063	12742	12749	12756	14	H	Y	148	F	A
5	064	12762	12773	12791	29	H	Y	305	F	A
5	065	12794	12805	12819	25	D	Y	284	F	A
5	066	12821	12826	12828	7	H	Y	60	F	A
5	067	12830	12834	12849	19	U	Y	193	S	A
5	068	12852	12855	12869	17	D	Y	137	U	A
5	069	12892	12918	12934	42	X	Y	232	S	A
5	070	12936		12943	7	X	Y	53	S	A
5	071	12959		12961	2	X	Y	27	S	A
5	072	12965	12983	13008	43	H	Y	175	S	A
5	073	13009		13023	14	D	Y	145	F	A
5	074	13076	13084	13094	18	H	Y	207	S	M
5	075	13097	13106	13138	41	H	Y	334	S	M
5	076	13148	13156	13157	9	X	Y	63	U	M
5	077	13161		13167	6	D	Y	49	F	M
5	078	13169		13175	6	D	Y	58	S	M
5	079	13175	13179	13183	8	X	Y	64	S	M
5	080	13226	13228	13236	10	X	Y	16	S	M
5	081	13238		13241	3	X	Y	55	S	M
5	082	13249	13256	13275	26	X	Y	226	U	M
5	083	13278	13285	13311	33	D	Y	218	S	M
5	084	13321	13323	13353	32	U	Y	147	S	M

Figure B.8 Frequency Five Raw Data Values, Continued.

NATIONAL TRAINING CENTER TAPES

FREQUENCY FIVE

FREQ NO	MSG NO	START TIME	COMMO ESTAB	STOP TIME	TOTAL TIME	MSG FLOW	INFO RQMT	CHAR/ MSG	TYPE REPT	ACTIVITY
5	085	13356		13396	40	U	Y	289	U	M
5	086	13431	13437	13506	75	X	Y	353	U	M
5	087	13513		13531	18	H	Y	80	S	M
5	088	13539		13545	6	D	Y	59	F	M
5	089	13546		13586	40	X	Y	456	S	M
5	090	13945	13966	13990	45	H	Y	282	U	M
5	091	13999		14027	28	U	Y	182	S	M
5	092	14093	14097	14119	26	D	Y	250	F	M
5	093	14239		14244	5	X	N	34	U	U
5	094	14245	14251	14308	63	U	Y	664	C	M
5	095	14379		14387	8	U	Y	50	C	A
5	096	14414		14417	3	X	N	59	S	A
5	097	14426		14442	16	X	N	68	S	A
5	098	14477		14480	3	U	N	38	U	A
5	099	14481		14490	9	D	Y	110	F	A
5	100	14519	14521	14544	25	H	Y	290	S	A
5	101	14572	14583	14591	19	D	Y	156	F	A
5	102	14598		14610	12	X	N	33	U	A
5	103	14637	14644	14646	9	D	Y	113	F	A
5	104	14661		14666	5	X	N	62	U	A
5	105	14690	14696	14710	20	U	Y	296	S	A
5	106	14719	14723	14754	35	H	Y	389	F	A
5	107	14822	14827	14837	15	H	Y	107	S	A
5	108	14846	14851	14868	22	H	Y	221	C	A
5	109	14870		14885	15	U	Y	106	S	A
5	110	14892	14899	14903	11	U	Y	90	U	A
5	111	14924		15067	143	D	Y	576	F	A
5	112	15079		15128	49	U	Y	220	S	A
5	113	15111		15115	4	X	Y	32	S	A
5	114	15210		15222	12	D	Y	157	F	A
5	115	15269	15274	15378	109	U	Y	564	U	A
5	116	15501	15505	15534	33	U	Y	254	U	A
5	117	15652		15655	3	U	N	42	S	A
5	118	15660	15669	15699	39	U	Y	244	U	A
5	119	15826		15840	14	H	Y	143	U	A
5	120	15976	15978	16022	46	U	Y	277	S	A
5	121	16024	16031	16060	36	D	Y	231	U	A
5	122	16061		16076	15	H	Y	164	U	A
5	123	16125		16130	5	D	Y	95	F	A
5	124	16144	16148	16196	52	D	Y	208	S	A
5	125	16202		16210	8	H	Y	131	F	A
5	126	16213		16215	2	X	N	19	U	A

Figure B.9 Frequency Five Raw Data Values, Continued.

NATIONAL TRAINING CENTER TAPES

FREQUENCY FIVE

FREQ NO	MSG NO	START TIME	COMMO ESTAB	STOP TIME	TOTAL TIME	MSG FLOW	INFO RQMT	CHAR/ MSG	TYPE REPT	ACTIVITY
5	127	16217		16241	24	H	Y	187	S	A
5	128	16243	16245	16317	74	D	Y	645	F	A
5	129	16389		16414	25	H	Y	202	F	A
5	130	16420		16432	12	D	Y	87	C	A
5	131	16411		16485	44	H	Y	175	S	A
5	132	16517	16521	16531	14	H	Y	107	S	A
5	133	16541	16546	16560	19	U	Y	198	S	A
5	134	16753		16755	2	D	Y	24	U	A
5	135	16780		16785	5	X	N	96	C	A
5	136	16814		16817	3	X	N	24	U	A
5	137	17008	17011	17026	18	D	Y	175	U	A
5	138	17027	17034	17069	42	D	Y	393	S	A
5	139	17079	17084	17127	48	U	Y	346	S	A
5	140	17131	17145	17160	29	H	Y	327	F	A
5	141	17163		17185	22	D	N	121	U	A
5	142	17247	17260	17274	27	D	Y	248	F	A
5	143	17293	17306	17324	31	H	Y	399	F	A
5	144	17440	17443	17502	62	U	Y	409	S	A
5	145	17506	17511	17524	18	U	Y	133	S	A
5	146	17535	17538	17571	36	D	Y	276	CFF	A
5	147	17688	17697	17703	15	U	Y	80	U	A
5	148	17745	17748	17785	40	H	Y	408	C	A
5	149	17944	17948	18005	61	H	Y	594	C	A
5	150	18015	18023	18034	19	H	Y	192	U	A
5	151	18035	18054	18085	50	H	Y	282	U	A
5	152	18111	18117	18128	17	U	Y	231	S	A
5	153	18151	18155	18159	8	U	Y	68	U	A
5	154	18361		18367	6	H	Y	77	U	A
5	155	18500		18520	20	H	Y	165	S	A
5	156	13539	18543	18556	17	U	Y	189	U	A
5	157	18727	18729	18747	20	U	Y	165	S	A
5	158	18750	18756	18802	52	U	Y	511	S	A
5	159	18895	18898	18955	60	H	Y	522	C	A
5	160	19132	19142	19159	27	U	Y	308	F	A
5	161	19190	19200	19210	20	U	Y	122	U	A
5	162	19571		19594	23	U	Y	80	S	A
5	163	19679	19684	19719	40	U	Y	250	U	A
5	164	19864	19868	19895	31	U	Y	197	C	A
5	165	20123		20155	32	D	Y	352	S	A
5	166	20229	20232	20239	10	D	Y	162	U	A
5	167	20345	20350	20402	57	U	Y	264	S	A
5	168	20476	20562	20593	117	H	Y	399	S	A

Figure B.10 Frequency Five Raw Data Values, Continued.

NATIONAL TRAINING CENTER TAPES

FREQUENCY FIVE

FREQ NO	MSG NO	START TIME	COMMO ESTAB	STOP TIME	TOTAL TIME	MSG FLOW	INFO RQMT	CHAR/ MSG	TYPE REPT	ACTIVITY
5	169	20597	20601	20621	24	D	Y	171	U	A
5	170	20658	20663	20735	87	U	Y	847	C	A
5	171	20741	20747	20750	9	U	Y	66	S	A
5	172	21115	21145	21150	35	H	Y	187	U	A
5	177	21440	21446	21493	53	D	Y	419	F	A
5	178	21498	21506	21519	21	U	Y	186	S	A
5	179	21521	21528	21539	18	X	Y	190	U	A
5	180	21567	21575	21591	24	H	Y	184	U	A
5	181	21668	21672	21686	18	X	Y	121	F	A
5	182	21736	21743	21747	11	X	Y	138	U	A
5	183	21878	21886	21888	10	X	Y	74	U	A
5	184	21889	21894	21896	7	D	Y	52	F	A
*** Total ***					5323			38993		

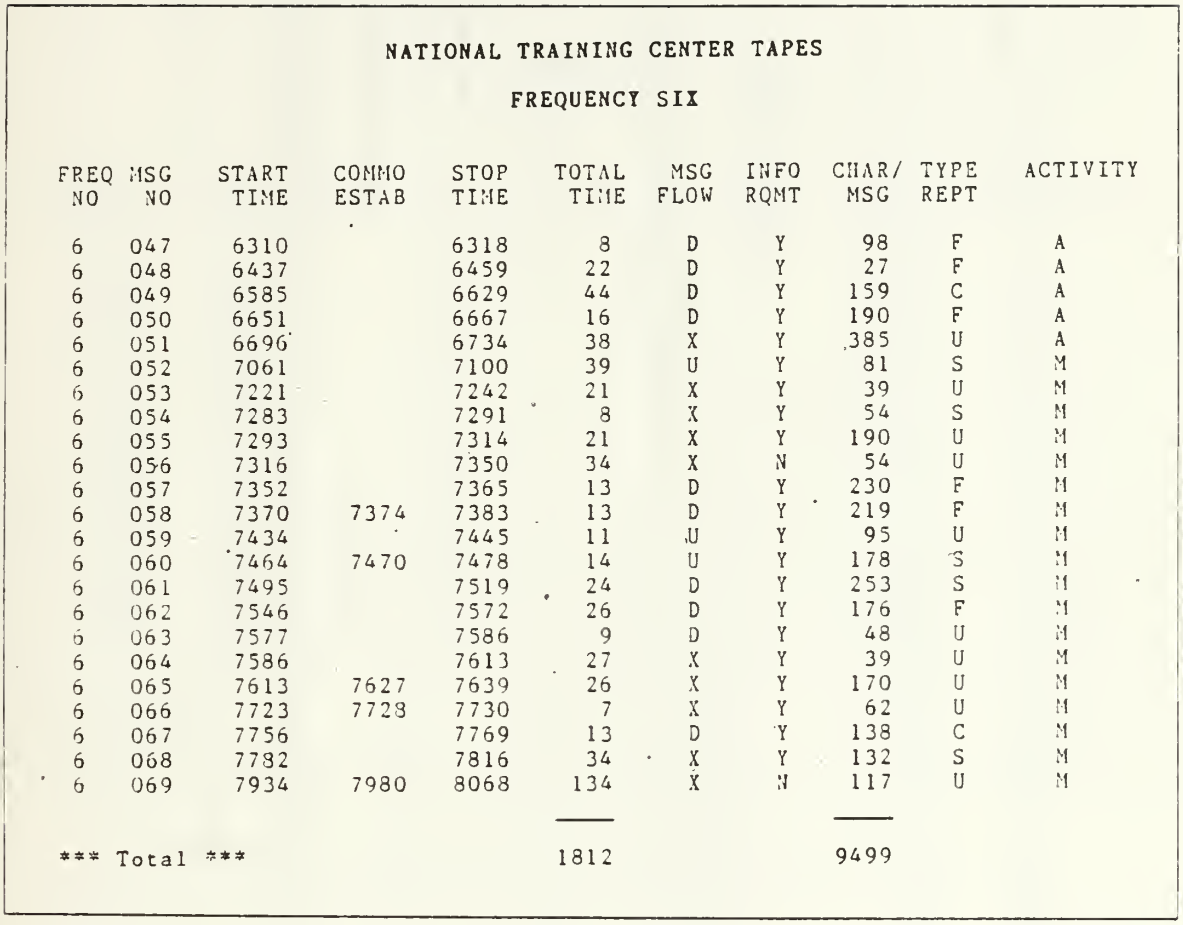
Figure B.11 Frequency Five Raw Data Values, Continued.

NATIONAL TRAINING CENTER TAPES

FREQUENCY SIX

FREQ NO	MSG NO	START TIME	COMMO ESTAB	STOP TIME	TOTAL TIME	MSG FLOW	INFO RQMT	CHAR/ MSG	TYPE REPT	ACTIVITY
6	001	588		620	32	D	Y	55	F	M
6	002	676		693	17	D	Y	86	F	M
6	003	1006		1035	29	U	Y	89	S	M
6	004	1120		1136	16	D	Y	159	F	M
6	005	1143	1157	1177	34	D	Y	117	U	M
6	006	1254		1257	3	X	Y	42	F	A
6	007	1285	1294	1331	46	D	Y	402	F	M
6	008	1393		1456	63	X	Y	325	F	A
6	009	1459	1473	1511	52	D	Y	294	U	M
6	010	1541		1551	10	D	Y	48	F	M
6	011	1553		1562	9	D	Y	188	F	M
6	012	1563		1624	61	D	Y	426	F	M
6	013	1627		1648	21	D	Y	120	F	M
6	014	1700	1708	1713	13	D	Y	110	U	M
6	015	1941		1973	32	D	Y	74	F	M
6	016	2027		2059	32	D	Y	88	U	M
6	017	2188		2216	28	D	Y	193	U	M
6	018	2218		2251	33	D	Y	220	S	M
6	019	2388		2413	25	D	Y	145	F	M
6	020	2626		2667	41	X	N	274	F	M
6	021	2992		3014	22	D	Y	58	U	M
6	022	3077		3105	28	D	Y	117	F	M
6	023	3237		3276	39	D	Y	200	S	M
6	024	3511		3528	17	D	Y	193	F	M
6	025	3931		3951	20	X	Y	119	F	M
6	026	4037	4044	4059	22	D	Y	243	F	M
6	027	4071		4073	2	D	Y	35	F	M
6	028	4073		4081	8	M	Y	61	U	M
6	029	4170		4173	3	D	Y	65	F	M
6	030	4206		4230	24	D	Y	93	F	M
6	031	4225		4234	9	D	Y	86	F	M
6	032	4250	4264	4296	46	X	Y	176	C	M
6	033	4300		4309	9	X	Y	45	S	M
6	034	4309		4337	28	D	Y	206	F	M
6	035	4598	4616	4618	20	D	Y	139	F	M
6	036	4620		4666	46	D	Y	89	F	M
6	037	4748		4766	18	D	Y	72	F	M
6	038	4905		4919	14	D	Y	175	F	M
6	039	5073		5088	15	X	Y	75	U	M
6	040	5184		5223	39	X	Y	93	F	M
6	041	5222		5227	5	U	Y	76	S	M
6	042	5233		5283	50	D	Y	242	C	M
6	043	5393		5405	12	D	Y	38	U	M
6	044	5420		5467	47	D	Y	51	F	M
6	045	5760		5790	30	X	Y	48	S	C
6	046	5962		6002	40	X	Y	115	C	A

Figure B.12 Frequency Six Raw Data Values.



NATIONAL TRAINING CENTER TAPES

FREQUENCY SIX

FREQ NO	MSG NO	START TIME	COMMO ESTAB	STOP TIME	TOTAL TIME	MSG FLOW	INFO RQMT	CHAR/ MSG	TYPE REPT	ACTIVITY
6	047	6310		6318	8	D	Y	98	F	A
6	048	6437		6459	22	D	Y	27	F	A
6	049	6585		6629	44	D	Y	159	C	A
6	050	6651		6667	16	D	Y	190	F	A
6	051	6696		6734	38	X	Y	385	U	A
6	052	7061		7100	39	U	Y	81	S	M
6	053	7221		7242	21	X	Y	39	U	M
6	054	7283		7291	8	X	Y	54	S	M
6	055	7293		7314	21	X	Y	190	U	M
6	056	7316		7350	34	X	N	54	U	M
6	057	7352		7365	13	D	Y	230	F	M
6	058	7370	7374	7383	13	D	Y	219	F	M
6	059	7434		7445	11	U	Y	95	U	M
6	060	7464	7470	7478	14	U	Y	178	S	M
6	061	7495		7519	24	D	Y	253	S	M
6	062	7546		7572	26	D	Y	176	F	M
6	063	7577		7586	9	D	Y	48	U	M
6	064	7586		7613	27	X	Y	39	U	M
6	065	7613	7627	7639	26	X	Y	170	U	M
6	066	7723	7728	7730	7	X	Y	62	U	M
6	067	7756		7769	13	D	Y	138	C	M
6	068	7782		7816	34	X	Y	132	S	M
6	069	7934	7980	8068	134	X	N	117	U	M
*** Total ***					1812			9499		

Figure B.13 Frequency Six Raw Data Values, Continued.

NATIONAL TRAINING CENTER TAPES

FREQUENCY SEVEN

FREQ NO	MSG NO	START TIME	COMMO ESTAB	STOP TIME	TOTAL TIME	MSG FLOW	INFO RQMT	CHAR/ MSG	TYPE REPT	ACTIVITY
7	001	403		410	7	D	Y	34	F	M
7	002	719		729	10	D	Y	45	F	M
7	003	1389	1402	1473	84	D	Y	237	F	A
7	004	1483	1488	1513	30	D	Y	92	F	A
7	005	1532	1545	1552	20	U	Y	90	C	A
7	006	1577	1584	1634	57	U	Y	152	C	A
7	007	1832	1834	1852	20	U	Y	61	S	M
7	008	1859	1862	1894	35	D	Y	125	S	C
7	009	1951		1955	4	D	Y	44	F	M
7	010	2011	2022	2032	21	U	Y	146	S	M
7	011	2170	2175	2202	32	D	Y	68	F	M
7	012	2232		2247	15	D	Y	34	U	M
7	013	2318		2324	6	D	Y	33	F	M
7	014	2508		2520	12	X	Y	39	U	A
7	015	2529		2536	7	D	Y	46	F	A
7	016	2566		2574	8	D	Y	79	F	A
7	017	2616	2625	2628	12	X	Y	114	F	A
7	018	2693		2698	5	U	Y	70	S	A
7	019	2827		2832	5	D	Y	49	F	A
7	020	3064		3070	6	D	Y	74	F	A
7	021	3107		3126	19	D	Y	140	F	A
7	022	3254	3258	3270	16	U	Y	98	S	A
7	023	3321		3328	7	D	Y	44	F	A
7	024	3375		3377	2	D	Y	28	F	A
7	025	3535		3558	23	D	Y	48	F	A
7	026	3639		3644	5	U	Y	42	S	A
7	027	3650		3655	5	X	N	29	U	A
7	028	3660		3666	6	X	Y	25	S	A
7	029	3667		3669	2	X	Y	29	S	A
7	030	3793		3809	16	X	Y	60	S	A
7	031	3829		3834	5	X	N	30	U	A
7	032	3909		3913	4	X	N	24	U	A
7	033	4154		4159	5	U	Y	56	S	A
7	034	4260		4268	8	D	Y	70	F	A
7	035	4766		4768	2	D	Y	33	S	A
7	036	4792		4795	3	U	Y	42	S	A
7	037	4977		4981	4	X	Y	39	C	A
7	038	5036		5038	2	D	Y	25	F	A
7	039	5145		5153	8	D	Y	84	F	A
7	040	5303		5321	18	D	Y	156	F	A
7	041	5389		5399	10	U	Y	111	S	A
7	042	5450		5452	2	X	Y	26	S	A
7	043	5470		5473	3	X	Y	26	S	A
7	044	5473		5476	3	X	Y	32	S	A
7	045	5484		5486	2	X	Y	39	S	A
7	046	5494		5496	2	X	Y	12	U	A

Figure B.14 Frequency Seven Raw Data Values.

NATIONAL TRAINING CENTER TAPES

FREQUENCY SEVEN

FREQ NO	MSG NO	START TIME	COMMO ESTAB	STOP TIME	TOTAL TIME	MSG FLOW	INFO RQMT	CHAR/ MSG	TYPE REPT	ACTIVITY
7	047	5531		5534	3	X	Y	39	S	A
7	048	5557		5559	2	X	Y	22	U	A
7	049	5575		5577	2	D	Y	16	U	A
7	050	6063		6071	8	D	Y	45	F	A
7	051	6174		6179	5	D	Y	59	F	A
7	052	6224		6226	2	X	N	19	U	A
7	053	6506		6511	5	D	Y	59	F	A
7	054	6798		6806	8	D	Y	103	F	A
7	055	6936		6942	6	D	Y	61	F	A
7	056	7223		7229	6	D	Y	52	F	A
7	057	7395	7403	7447	52	X	N	263	U	A
7	058	8284	8286	8298	14	X	Y	60	C	A
7	059	8684	8700	8729	45	X	Y	277	U	A
7	060	9104	9115	9118	14	U	Y	122	S	A
7	061	9605	9615	9621	16	U	Y	49	S	A
7	062	9872	9879	9923	51	U	Y	290	S	A
7	063	10318		10391	73	X	Y	342	C	A
*** Total ***					890			4858		

Figure B.15 Frequency Seven Raw Data Values, Continued.

APPENDIX C
DATA AVERAGES AND MAXIMUMS

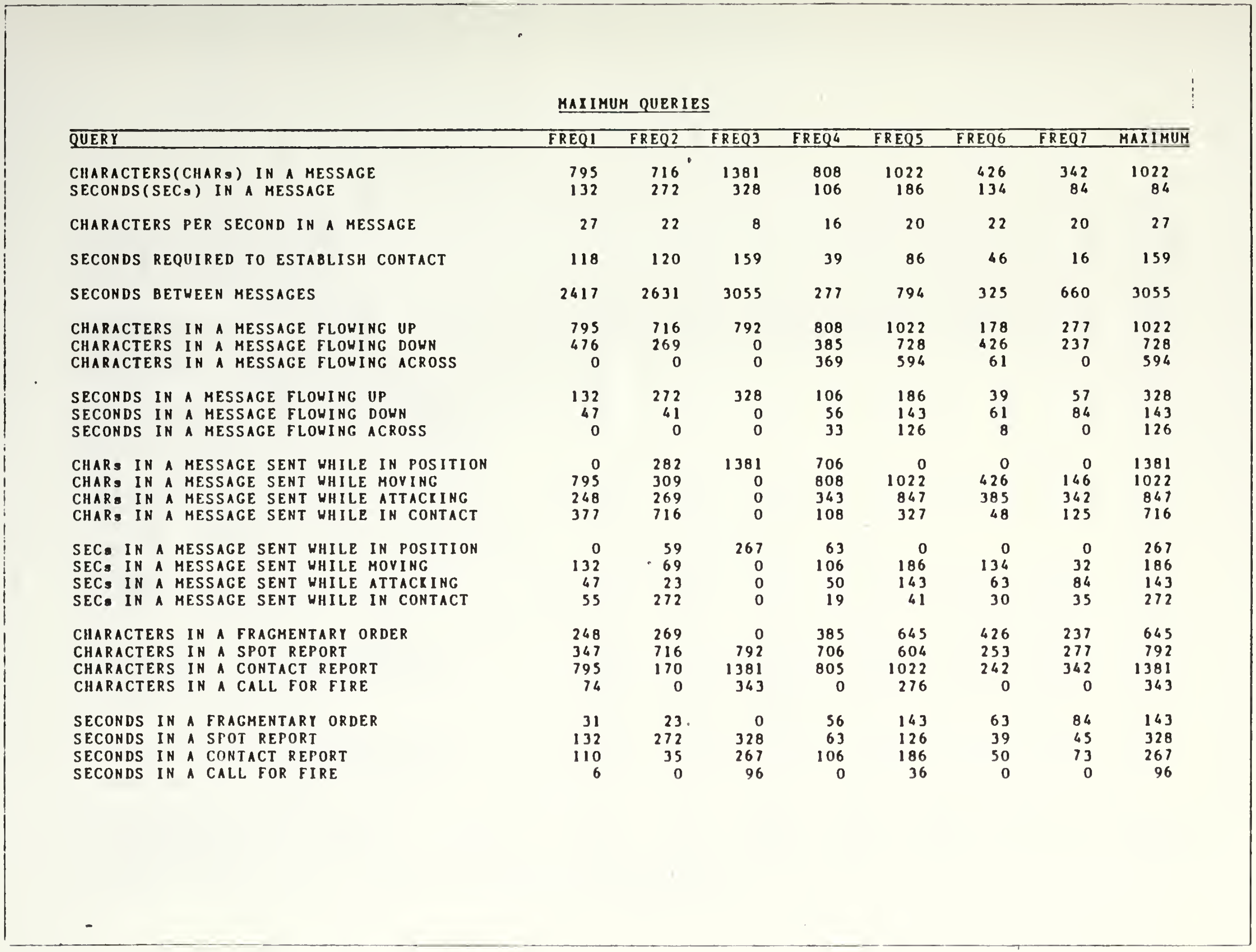
The following pages provide a summary of all of the results of the different queries asked of the database for this thesis. It is intended to be a quick reference for the analyst who desires a look at the data in its entirity and does not want to observe any one aspect of the data in detail, which is the manner in which it was presented in the text of the thesis. The first figure, Figure C.1, provides a summary of the averages for each of the queries. These averages were taken from each frequency used in the sample and are for the sole purpose of providing a perspective to the maximums achieved. They were not used in anyway to draw conclusions from the research. The respective average values for each frequency is represented as a distinct entity, and the average for the database as a whole is provided in the right-most column.

The second figure, Figure C.2, provides a summary of the maximums for each of the queries across the seven frequencies. These maximums represent the parameters of system utilization that were used to profile the voice requirements for the selected sample. This figure shows the respective maximum data values for each frequency as a distinct entity, and the maximum for the database as a whole is provided in the right-most column. See below.

AVERAGE QUERIES

QUERY	FREQ1	FREQ2	FREQ3	FREQ4	FREQ5	FREQ6	FREQ7	AVERAGE
CHARACTERS(CHARs) IN A MESSAGE	135	131	415	193	77	138	77	167
SECONDS(SECs) IN A MESSAGE	21	28	107	24	14	26	14	33
CHARACTERS PER SECOND IN A MESSAGE	18	4	5	11	5	2	5	7
SECONDS REQUIRED TO ESTABLISH CONTACT	21	16	40	8	8	13	8	16
SECONDS BETWEEN MESSAGES	135	183	586	68	91	83	147	185
CHARACTERS IN A MESSAGE FLOWING UP	207	203	457	248	101	104	101	203
CHARACTERS IN A MESSAGE FLOWING DOWN	103	95	0	164	69	148	69	108
CHARACTERS IN A MESSAGE FLOWING ACROSS	0	0	0	196	0	61	0	129
SECONDS IN A MESSAGE FLOWING UP	39	57	155	31	18	20	18	48
SECONDS IN A MESSAGE FLOWING DOWN	11	12	0	19	13	24	13	15
SECONDS IN A MESSAGE FLOWING ACROSS	0	0	0	18	0	8	0	13
CHARs IN A MESSAGE SENT WHILE IN POSITION	0	153	1087	279	0	0	0	506
CHARs IN A MESSAGE SENT WHILE MOVING	141	107	0	209	58	135	58	118
CHARs IN A MESSAGE SENT WHILE ATTACKING	140	96	0	106	79	168	79	111
CHARs IN A MESSAGE SENT WHILE IN CONTACT	104	208	0	108	125	48	125	120
SECs IN A MESSAGE SENT WHILE IN POSITION	0	33	243	29	0	0	0	102
SECs IN A MESSAGE SENT WHILE MOVING	23	15	0	25	14	26	14	20
SECs IN A MESSAGE SENT WHILE ATTACKING	17	10	0	18	14	29	14	17
SECs IN A MESSAGE SENT WHILE IN CONTACT	12	73	0	19	35	30	35	34
CHARACTERS IN A FRAGMENTARY ORDER	79	76	0	168	73	149	73	103
CHARACTERS IN A SPOT REPORT	130	213	399	184	72	125	72	171
CHARACTERS IN A CONTACT REPORT	324	148	862	375	196	166	196	348
CHARACTERS IN A CALL FOR FIRE	74	0	343	0	163	0	0	193
SECONDS IN A FRAGMENTARY ORDER	8	8	0	19	13	24	13	14
SECONDS IN A SPOT REPORT	26	61	126	24	11	24	11	40
SECONDS IN A CONTACT REPORT	39	23	182	50	43	39	43	60
SECONDS IN A CALL FOR FIRE	6	0	96	0	0	0	0	51

Figure C.1 Summary of Database Averages.



MAXIMUM QUERIES

QUERY	FREQ1	FREQ2	FREQ3	FREQ4	FREQ5	FREQ6	FREQ7	MAXIMUM
CHARACTERS(CHARs) IN A MESSAGE	795	716	1381	808	1022	426	342	1022
SECONDS(SECs) IN A MESSAGE	132	272	328	106	186	134	84	84
CHARACTERS PER SECOND IN A MESSAGE	27	22	8	16	20	22	20	27
SECONDS REQUIRED TO ESTABLISH CONTACT	118	120	159	39	86	46	16	159
SECONDS BETWEEN MESSAGES	2417	2631	3055	277	794	325	660	3055
CHARACTERS IN A MESSAGE FLOWING UP	795	716	792	808	1022	178	277	1022
CHARACTERS IN A MESSAGE FLOWING DOWN	476	269	0	385	728	426	237	728
CHARACTERS IN A MESSAGE FLOWING ACROSS	0	0	0	369	594	61	0	594
SECONDS IN A MESSAGE FLOWING UP	132	272	328	106	186	39	57	328
SECONDS IN A MESSAGE FLOWING DOWN	47	41	0	56	143	61	84	143
SECONDS IN A MESSAGE FLOWING ACROSS	0	0	0	33	126	8	0	126
CHARs IN A MESSAGE SENT WHILE IN POSITION	0	282	1381	706	0	0	0	1381
CHARs IN A MESSAGE SENT WHILE MOVING	795	309	0	808	1022	426	146	1022
CHARs IN A MESSAGE SENT WHILE ATTACKING	248	269	0	343	847	385	342	847
CHARs IN A MESSAGE SENT WHILE IN CONTACT	377	716	0	108	327	48	125	716
SECs IN A MESSAGE SENT WHILE IN POSITION	0	59	267	63	0	0	0	267
SECs IN A MESSAGE SENT WHILE MOVING	132	69	0	106	186	134	32	186
SECs IN A MESSAGE SENT WHILE ATTACKING	47	23	0	50	143	63	84	143
SECs IN A MESSAGE SENT WHILE IN CONTACT	55	272	0	19	41	30	35	272
CHARACTERS IN A FRAGMENTARY ORDER	248	269	0	385	645	426	237	645
CHARACTERS IN A SPOT REPORT	347	716	792	706	604	253	277	792
CHARACTERS IN A CONTACT REPORT	795	170	1381	805	1022	242	342	1381
CHARACTERS IN A CALL FOR FIRE	74	0	343	0	276	0	0	343
SECONDS IN A FRAGMENTARY ORDER	31	23	0	56	143	63	84	143
SECONDS IN A SPOT REPORT	132	272	328	63	126	39	45	328
SECONDS IN A CONTACT REPORT	110	35	267	106	186	50	73	267
SECONDS IN A CALL FOR FIRE	6	0	96	0	36	0	0	96

Figure C.2 Summary of Database Maximums.

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